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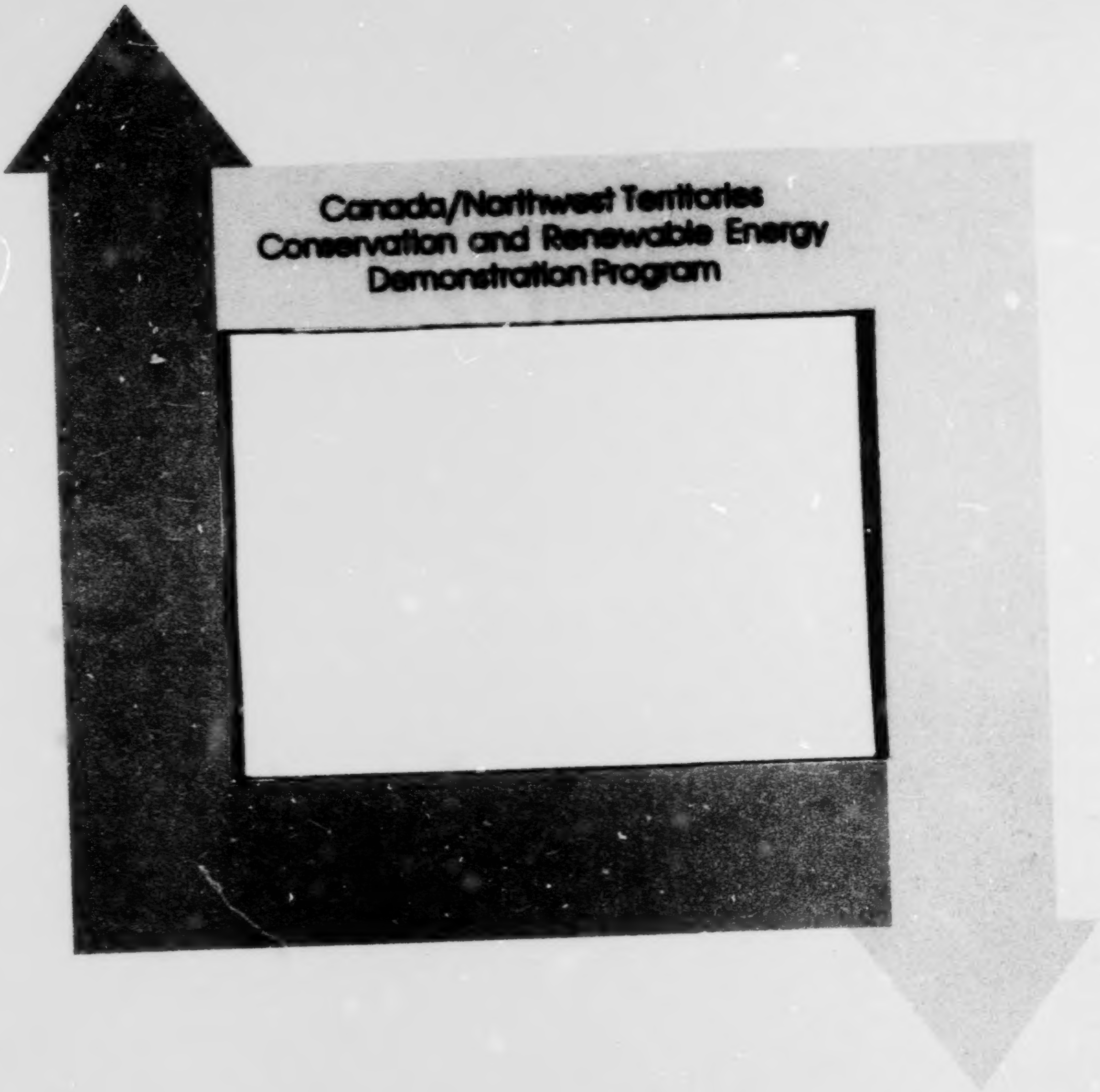


Canada/Northwest Territories Conservation and Renewable Energy Demonstration Program

Energy, Mines and Resources Canada
Energie, Mines et Ressources Canada

Northwest Territories Public Works

WASTE HEAT
RECOVERY
RETROFIT PROJECT

Prepared By

FERGUSON, SIMEK, CLARK LTD

NORTHWEST TERRITORIES / CANADA CONSERVATION AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the governments of N.W.T. and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement which was signed March 24, 1980 and terminates March 31, 1984. The Agreement is dedicated to the development and demonstration of conservation and renewable energy technologies. Cost-shared by the territorial and federal governments, the program has a total budget of $3.3 million.

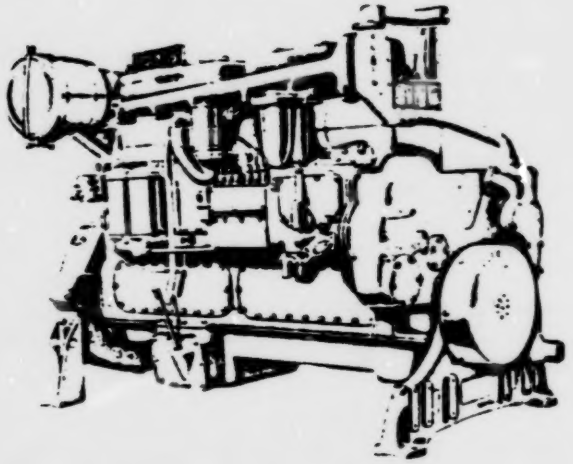
The objectives of CREDA are:

- To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- To develop broad public awareness of the potential of renewable energy and conservation technology.
- To provide opportunities for the commercial application of the technologies.
- To create economic spin-off benefits for manufacturing, industry and commerce.
- To create employment in new or existing energy-related industries.

LAC LA MARTRE SCHOOL
NORTHWEST TERRITORIES

HEAT RECOVERY RETROFIT PROJECT

ENERGY, MINES AND RESOURCES CANADA
&
ENERGY CONSERVATION DIVISION
DEPARTMENT OF PUBLIC WORKS
GOVERMENT OF THE NORTHWEST TERRITORIES



THIS PROJECT WAS CONVENED BY
CANADA/NORTHWEST TERRITORIES
CONSERVATION AND RENEWABLE ENERGY
DEMONSTRATION PROGRAM

AUGUST, 1983

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1.0

SYNOPSIS

1.0 SYNOPSIS

This report was commissioned by CREDA to provide the results of the experience gained and guidance for the replication of a waste heat recovery system in Lac La Martre, N.W.T.

The project demonstrates the economic and technical viability of recovering the waste heat, which is produced by the community's generator motors, and reusing it to almost totally heat the local school.

From an initial capital outlay of $250,000, savings for fuel of $26,000/annum are now being realized, with a total payback period of 9 years.

7

1.0 SOMMAIRE

Ce rapport a ete commande par "CREDA" afin de publier les resultats et l'experience acquis et ainsi nous permettre de repeter le systeme de recuperation de la chaleur residuaire du Lac La Martre T.N.O.

Le projet a demontre qu'il est techniquement possible de recuperer la chaleur residuaire provenant des generateurs de la communaute et de s'en servir pour presque totallement chauffer l'e-l'ecole.

D'un investissement de $250,000, des epargnes de $26,000 par annee, sur le cout du chauffage, sont presentement realisees tout en permettant un repaiement de la dette dans une periode de 9 ans.

2.0

INTRODUCTION

2.0 INTRODUCTION

In the summer of 1981, a new school of 1,800 sq. meter (18,000 sq. ft.) was built in Lac La Martre, N.W.T. The school incorporated many energy conservation features.

Motivation for the Government of the Northwest Territories (G.N.W.T.) and Northern Canada Power Commission (N.C.P.C.) to consider diesel generator waste heat retro-fit was precipitated by the rise in fuel prices during the Seventies. Since most of the communities throughout the N.W.T. derive electrical energy from fossil fuels, it is apparent that the north faces a certain operational cost vulnerability for which there are no realistic alternatives for the forseeable future. For this reason, long range planning strategy must centre the maximum utilization of long range fuel. The energy equation for thermal power stations best emphasizes the renewed interest in waste heat recovery. Simply stated:

> For each three units of fuel delivered to the generator, approximately one is transformed into electrical power; the remaining two units are rejected as heat, primarily through the cooling water and exhaust gases.

A survey was completed in 1980 by consultants Ferguson, Simek, Clark Ltd. of Yellowknife, N.W.T., to assess the potential markets for Heat Recovery. In summary, over the 42 potential sites where waste heat could be successfully utilized, a total annual saving of approximately $88 million could be achieved, with an average payback period on the initial capital cost of 10 years.

The technical aspects of waste heat recovery and total energy systems are well understood and have been in widespread use for many years. Historically, the emphasis has been on total energy design for new installations co-ordinating heat produced and used with an overall masterplan.

Recent interest (and this project and report in particular), concerns waste heat recovery centered on the retrofit of existing generating plants and markets.

Many potential customers, both in the public and private sectors, have viewed the distribution of waste heat as experimental and therefore unreliable. It is expected that the Lac La Martre project will go some way in lessening those fears and in providing hard facts of the possible energy, and ultimately, financial savings.

2.0 PRESENTATION

Au cours de l'été de 1981, une nouvelle école de 1,800 m. carré (18,000 pi.carre) fut érigée a Lac La Martre T.N.O. Cette école incorporait plusieurs innovations dans la conservation de l'énergie.

La raison principale qui a motivé le Gouvernement des Territoires du Nord-Ouest (G.T.N.O.) et la Commission d'Electricité du Nord Canadien (C.E.N.C.) à considérer l'usage de la chaleur résiduaire des générateurs diesel, fut la hausse du coût du carburant de chauffage durant les années soixante-dix. Etant donné que la majorité des communautés des T.N.O. obtiennent leur énergie électrique de carburants, il est évident que le nord est exposé à des hausses de coûts desquel le nord ne peut se protéger. C'est pour cette raison que de la plannification doit se concentrer sur l'utilisation maximale des carburants. Faire la calculation de l'énergie des stations génératrices thermales démontrent l'intérêt ravive sur l'usage de la chaleur résiduaire.
Tout simplement dit:

> De trois unités de carburant livrées aux générateurs, une est transformée en électricité tandis que les deux autres sont tout simplement perdues en chaleur par soit l'agent de refroidissement ou par les évacuations de gaz.

Une étude complétée en 1980 par les consultants Ferguson, Simek, Clark Ltée. de Yellowknife T.N.O., donne un aperçu des marches dans le recouvrement de la chaleur résiduaire. En résumant, des 42 sites potentiels ou le recouvrement de la chaleur résiduaire est faisable, une épargne totalle annuelle estimée à $88 million peut être réalisée ceci incluant une période de repaiement de 10 années sur l'investissement capital.

L'aspect technique du recouvrement de la chaleur résiduaire et des systèmes d'énergie est bien connu et est en usage depuis deja plusieurs années. Historiquement, l'importance fut concentrée sur l'efficacité du développement de nouvelles installations en faisant la coordination entre la chaleur produite et qui est mise a l'usage l'incluant dans une plannification totalle et maîtresse.

Les intérêts récents (et tout particulièrement ce projet-ci), sont sur le recouvrement de la chaleur résiduaire en se concentrant sur la modification de génératrices et marchés déjà en existence.

Bien des propects, dans les secteurs publics et privés, considèrent que la distribution de la chaleur résiduaire n'est qu'au point experimental et n'est donc pas encore fiable. Il est a espérer que le projet du Lac La Martre aidera grandement a éliminer ces doutes en fournissant des faits établis dans les épargnes d'énergie et financiers.

3.0

LAC LA MARTRE COMMUNITY

3.0 LAC LA MARTRE COMMUNITY

Lac La Martre is a small fish and fur harvesting community of approximately 250 people. It is situated 164 air kilometres northwest of Yellowknife and is typical of many of the small communities across the north.

The area is the traditional homeland of the Dogrib Dene and a settlement has existed there since the 1800's. Although a small school was constructed in 1955 and an attempt was made to establish a commercial fishery and processing plant, the community has undergone little development and remains a Dene trapping communtity.

HISTORY OF PROJECT

The old school buildings required replacement due to overcrowding, poor facilities and inefficient use of space and energy. It was decided to build a new school which could double as a community centre with extensive evening and weekend use. The school was to be designed with its own emergency power source in order that, it could be totally self-sufficient, acting as a shelter for the entire community in an emergency.

Siting of the school is 100 metres from the existing NCPC generating building, and provided an obvious opportunity to demonstrate how total waste heat could be utilized.

COMMUNITY DATA

Location	63°08'N, 117°16'W. Elevation 271m at the airstrip. 164 air km 164 air NW of Yellowknife, On the southeast shore of Lac La Martre.
Topography	On flat lowland with marshy terrain to the northeast and south, surrounded by taiga forest.
Climate	Average annual precipitation: 12.7cm rainfall, 111.8cm snowfall, 22.9cm total precipitation. July mean high 25.6°C, low 12.2°C, January mean high -23°C, low -32.7°C, winds E at 8.7 knots.

Infrastructure

Power: NCPC (Area Office Yellowknife), diesel generator, 310KW capacity. 1983 rates, Domestic Service (non-government): 12.04¢/kwh for first 300KWH per month, 27.06¢/kwh for all over 300KWH per month. Commercial Service (government): 56.90¢/KWH. Domestic Service (government): 57.26¢/KWH. Commercial Service(non-gov't) : 43.73¢/KWH.

Water: Water is hauled from a lake, 2.5km from the settlement and transported by wagon to storage tanks.

Sanitation: Most residents utilize honey buckets. The old school and government buildings have septic tanks.

Fuel: GNWT retail prices for 1983: P-50 heating, $.58/litre.

TRANSPORTATION

Air: There is an unlicensed 671mx21m sand and clay runway. There is limited airfield maintenance and Ptarmigan Airways operate a scheduled service via Yellowknife.

Road: Winter road connecting to Mackenzie Highway at Rae, providing access to Yellowknife for two months of the year.

4.0

PRELIMINARY DESIGN CONSIDERATIONS

4.0 CONSTRUCTION CONSIDERATIONS

Lac La Martre, like many northern communities, is not served by an all weather road. The only access is by air or by the winter ice road which is open for approximately two months of the year. The town's clay and gravel airstrip is too short for a Hercules or DC3 aircraft so that the only economical haulage route is via the winter ice road.

As the town is isolated, the cost of flying in materials and maintenance staff is high. Therefore, the mechanical system design for both the school and the heat recovery equipment incorporated into the NCPC plant, had to be kept as simple and maintenance-free as possible and still meet the energy objectives.

On the other hand, due to the unfavourable climate, the high cost of electricity and fuel oil, the school design required the incorporation of a high degree of energy conservation and associated controls to maximize use of the wasteheat available. It was considered that the advantages of much lower running costs would outweigh the disadvantages more sophisticated controls.

The consultants and NCPC co-ordinated the design through the initial stages. NCPC were responsible for all the work associated with their equipment, including the design and installation. NCPC are obviously concerned about the effect any modification work would have on their equipment and it is important that they are fully involved at the design stage in order that no maintenance problems are created by any alterations.

A design balance was required that would prove to be acceptable to all parties - the community, the maintenance staff, NCPC, GNWT and the design consultants.

PRE-DESIGN INVESTIGATION

The project depended on the supplier (NCPC) and the user (GNWT) reaching a satisfactory arrangement technically, administratively and financially. The supplier and user had different and sometimes conflicting interests. NCPC wanted to protect their engines, keep maintenance costs down and eliminate system complications. The GNWT wanted a sufficient supply of high grade heat with as few technical problems as possible.

PRELIMINARY DESIGN

The siting of the school in relation to the NCPC plant provided a straightforward solution to the routing of heating lines between the school and the NCPC generators. The pipes would be buried beneath the playing fields, entering the school through the crawlspace, where they provided partial heating, before passing into the boiler room. (See Figure 3).

Preliminary load calculation revealed the need to use both the waste heat from the generators' coolant water and the flue gas. (See Figure 7). In all projects previously handled, the jacket water heat was more than sufficient to handle the market requirements. This was the first attempt to be made to incorporate an exhaust boiler in a retrofit project, and complicated the recovery process from N.C.P.C.'s point of view vis-a-vis the unknowns about remote plant reliability.

5.0

SYSTEM DESIGN

5.0 SCHOOL HEATING SYSTEM

Apart from certain additional energy conservation measures which have been incorporated into the mechanical design (see Appendix 'A5'), the school's heating system consists of conventional perimeter baseboard heating, together with two ventilation systems supplying tempered outside air as required.

The domestic hot water is supplied by the waste heat with cold water being circulated through tankless heat exchangers and stored in insulated tanks. An electric heater was installed as emergency backup only.

NCPC TO SCHOOL HEATING PIPES

The heating system is filled with a pre-mixed solution of 50% Propylene Glycol and 50% water. Freezing of the heating fluid is not a risk so that any insulation provided around interconnecting pipework is for heat loss purposes only.

Pipe: 63mm Ø schedule 40 welded steel pipes.

Insulation: 38mm thick polyethylene insulation and 45 mil polyethylene black jacket. The black jacket is more resistant to ultra-violet light than the yellow jacket and was chosen because it was anticipated that the pipes would be stored in the open for a few months before installation.

Pipe Depth: 600mm.

Installation: Soils are not thaw stable in permafrost so that timber sleepers were used, extending beyond the influence of the thaw bulb created by the pipes.

See figures 3 and 4 for further details.

SCHOOL HEATING SYSTEM OPERATION

The school heating system was designed to be completely self-contained, with two oil-fired boilers capable of providing the necessary heat. However, the intention of the design was to use as much of the waste heat from the NCPC generating plant as possible. This would mean that the school boilers' operation would be kept to a minimum. It was anticipated that some peaking at design conditions would be required from the boilers.

The school heating system was designed to operate at 62°C which could normally be supplied from the NCPC recovery lines. (See Figure 6).

The hot water passes in series from the NCPC recovery lines through the boilers, which will make the water up to 62°C, with an operating aquastat controlling the boilers when NCPC cannot supply enough heat. It was anticipated that this situation would only arise on the colder winter days when the generating plant was operating at a low capacity such as mid morning, mid afternoon and after midnight.

If the NCPC water temperature supply falls below 49°C, the heat recovery line aquastat modulates a 3-way valve to recirculate the water back to NCPC rather than through the school heating system. This is to prevent the situation where the heat flow is reversed, and the boilers are providing heat to the NCPC plant.

The school heating system has separate pumps. The additional pumps which circulate the hot water between the school and the NCPC building are also situated within the school boiler room.

A thermostat located on the heating water supply line will initiate an alarm when the temperature drops below 43°C.

With the incorporation of the night setback features, the generator supply and school demand are in phase both daily and seasonably. For this reason, analysis has shown that storage is not a significant issue.

NCPC HEAT RECOVERY SYSTEM

Due to the heating load and plant heat output, it was necessary to recover the waste heat both from the generators' jacket water and from their exhaust flue gas. It is our first major project to use both waste heat sources from the town's main diesel generating plant in a retrofit application.

The primary concern of NCPC was that the new equipment would not adversely affect the operation of the generating equipment. They did not want increased maintenance costs imposed by unreliable equipment and intricate controls, and also needed assurances that the connecting system would be perfectly safe.

These usual NCPC conditions indictated that the school heating system would be on a self-contained secondary system, making possible complete isolation should future problems from either system arise. Instances such as leaking engine oil into the jacket water, or breakdown of the school circulating pumps, would be isolated.

The engine operating temperatures and pressures must remain within acceptable limits, regardless of downstream demand for the recovered heat. Controls and interfaces were required to operate in such a way that failure would occur in a "safe" direction to protect the generating plant.

From preliminary calculations it was seen that not enough heat would be rejected from the jacket water to totally heat the school in winter. The water cooling circuits removes 30% of the energy input to the engine. Engine operation must be kept fairly constant at 70°-90°C. It is important that the jacket water not be overcooled. Temperature differences between water inlet and outlet to the engine should be between 5.5°C-8.3°C.

The school heating system has a high thermal inertia modulating slowly with outside temperature variation. A "buffer" storage tank, which helps to minimize thermal stresses to the engine due to quickly changing loads, was therefore unnecessary.

The exhaust gas also has limitations as to how much heat recovery can be allowed. 50-60% of the gas heat can be recovered depending on the initial temperature but the gas temperature must not fall below 170°C, which is still above the condensation temperature of the gas stream.

The primary aim of the exhaust heat recovery design should be to minimize the back pressure introduced, since restriction of the exhaust gas flow causes loss of horsepower and increased operating temperatures, with uncertain effects on the exhaust valves.

OPERATION

The school heating system is connected to the generators' motors cooling water system via a plate heat exchanger. This is the primary heat source. At the design stage it was anticipated the additional heat output from the flue gases would also be required during the colder winter months. As explained later in the report, the exhaust boiler is being used in the summer as well.

Generally NCPC prefer to duplicate their engine cooling system so that a leak or breakdown in one system does not totally break the town's electrical supply. The generating system was considered too small in this case as one outdoor radiator adequately rejects all the jacket water waste heat.

During design, every load condition must be considered. When the generator output is large and the school load is minimal, a situation would arise where the radiator would have to reject both the jacket water heat and the heat from the exhaust boiler. The existing radiator is not large enough and the alternative of incorporating a bypass to the exhaust boiler was used. A control valve diverts the flue gas to atmosphere via a conventional muffler when heat recovery is not called for.

SYSTEM EQUIPMENT

NCPC GENERATING EQUIPMENT

There are three generators which handle the total power supply for Lac La Martre.

#1: Make and Model: DD4-71 (4 Cylinder)
: 80 KW @ 600V and 1800 RPM
: Equipped with "Tamper" 125 Kva generator.

#2: As #1.

#3: Make and Model: Caterpillar D-342 (6 Cylinder)
: 150 KW @ 600V and 1200 RPM
: Equipped with "Kato" 187.5 kVa generator.

Units #1 and #3 are hooked to the heat recovery system.

Note: In May 1983, the generating system was upgraded. Generator #1 was replaced with a larger unit; Caterpillar 3406 with 281.25 kVa generator. This new unit was hooked up to a new outdoor radiator and connected into the existing heat recovery system.

There was also much general upgrading performed at this time, with new gauges, access ladders and monitoring equipment.

SCHOOL HEATING EQUIPMENT

The school is provided with two boilers which are sized to handle the complete heating load.

#1: Weil-McClain Model "ABL976-W-T1H" with 159 KW output.

#2: As #1.

CIRCULATING PUMPS

Two pumps were installed in the school boiler room to continuously circulate the waste heat from the NCPC building to the school.

Pumps (one standby): Armstrong H54.
Capacity 2.53L/S @ 7.9m head
3/4 HP, 208V/3/60 motor

BTU METER

A BTU meter is located in the school mechanical room (see Figure 6) and connected to sensors and a water meter in the NCPC heat recovery pipes.

The data sheets are included in Appendix A3 and show the figures collected by the school maintenance staff from the meter. They are:

1. Water Supply temperature into school (°C).
2. Water Return temperature to NCPC.
3. Water Volume (m3).
4. Heat Load (MWh).

BTU METER TECHANICAL DATA

Meter: Kamstrup - Metro A/S electronic heat meter for mains supply, complete with a 65mm water meter c/w pulse generator.
Summation units: MWH and m3

Range of temperatures: 0-120°C.
Accuracy: Exclusive of phials and water meter
± 0.2% ± 0.2°C.
Power Supply: 220V, 60 cycles
Ambient temperature: -10 + 50°C

6.0 POSSIBLE ANALYSIS FROM READINGS

Once a set of readings is obtained over a particular time period, there are certain conclusions that can be drawn and assumptions made.

Two readings of water flow rate cubic (meter) over a specified time period tell us the flow of hot water being passed from the NCPC heat recovery equipment into the school.

If we know that the school boilers have not fired during the measured time, then the water supply and return temperatures, together with the water flow rate, can tell us the heating load of the school over that particular time period. We use the following equation:

$$Q = m.s.dt$$

Where Q = School heating load (kilowatts).
m = Flow rate of the hot water (litres/second).
s = Specific heat of water (4.18 kilojoules/kilogram °C).
dt = Difference between water supply and return temperature (°C).

Whenever the NCPC waste heat is insufficient to heat the school, the boilers will fire and readings from the oil meter, connected to the inlet of the day tank, will enable us to calculate the amount of supplemental heat and oil consumption, over the heating season.

The Heat Load, read from the meter in Megawatt Hours (MWH) tells us the total energy absorbed by the school from NCPC's waste heat.

For example: If the school heating load over a period of 3 hours was a constant 150 KW, the total energy absorbed in that time would be 450 KW hours or 0.45 MW hours.

6.0

FIELD WORK

SITE VISITS

1. Winter 1983

The results of this site visit are given in Table 1.

Observations

With the outside temperature at -24°C, this could be considered a fairly typical winter's day. Our first observation, as we walked past the NCPC generating building was how quiet the equipment was. All the flue gases were being discharged through the heat recovery silencer and as a result the "bypass flue" was icing up due to infrequent use (see Photograph P6).

The school boilers did not fire during our 1 1/2 hours stay showing us that the school was being totally satisfied by NCPC's waste heat.

It was also noticed that the NCPC radiator, which is normally used to dissipate the engine's waste heat, was cold. From this observation, we made the assumption that the total recoverable heat from the generating plant was being used by the school. When the load on the generator at the time was 100KW, or 66% load.

Calculations

In addition to the information shown in Table 1, the following readings were recorded.

Average No. of Degree Days in January = 1360
Outside Temperature = -24°C
Predicted No. of Degree Days for
January 7, 1983 = 18 - (-24)
= 42

NCPC Readings: Generator Electrical Output = 100 KW
Water Temp. into Plate
Heat Exchanger = 50°C
Water Temp. out of Exchanger = 60°C

Water Temp. into Exhaust Boiler = 60°C
Water Temp. out of Exhaust Boler = 65°C

From all these readings we can calculate the following:

Heating Water Flow into School = 8.5m3 in 67 minutes
= 2.11 L/S

School Heating Load = m.s.dt
At -24°C Outside Temp. = 2.11x4.18x15
= 132.3 KW

2. Summer 1983

Observations

The outside air temperature was 15° C which is typical for a Summer's day in Lac La Martre. At the time of this visit the NCPC building was in the process of being upgraded. New gauges and metering equipment were being installed and the staff are obviously taking a close interest in how the heat recovery system is working and how it is affecting their equipment. One of the smaller generators had been replaced by a larger model (see Systems Design) and its engine connected into the heat recovery system. A new outdoor radiator had also been installed for the new engine.

Both the radiators were cold and we were surprised to find that the exhaust boiler was being used. The flue gas temperature dropped from 300° C to 180° C through the exchanger. Actual water temperatures could not be taken as the gauges had temporarily been removed.

At the school we found both ventilation supply fans operating, together with both the pumps for the heating coil circuit and that for the radiation circuit.

The load on the one generator that was running, was 65 kW, or 43% load.

NCPC WINTER SITE VISIT

New information is constantly being obtained through site visits, NCPC and communication with the school. A 3-day site visit by NCPC's maintenance staff in February provided us with some valuable information. The observations that were recorded included:

1. During the hours 0900 to 1900, the school's heat demand was sufficient to ensure complete engine cooling.

2. During the hours 1900 to 0900, the NCPC plant's cooling system, i.e., the radiator, is utilized on an intermittent basis.

3. The NCPC loads ranged from a low of 80 KW to a high of 145 KW. Generally the steady day and night loads were 100 KW and 80 KW respectively.

4. The boilers did not fire during the 3-day visit. The outside day time temperatures averaged -20°C falling to -30°C at night.

INTERIM PREDICTIONS (February 1983)

In February, in the middle of the heating season, the following observations were made from the predictions produced in Table 2.

"The NCPC Heat output will totally satisfy the school's heating requirements during the months April-October. The 'supply' and 'demand' figures are far enough apart for us to confidently assume this to be the case. In fact, it is possible that the generators' jacket water waste heat will be sufficient to provide the heat requirements.

As the temperature falls in November, the school heat load climbs sharply and it is possible that the boilers will be required to fire occasionally to handle instantaneous peaks.

During the winter months of December, January and February, the NCPC waste heat should still provide the majority of the school's heat source, but the boilers may be required to handle peaks as required.

As outlined in the "Limitations" of this section, the tables do not tell us what is happening from hour to hour. The generating output is not constant, but rises and falls during the day and night. Similarly, the school heat requirement changes with temperature, wind, occupancy and night setback. There may be times when the school has surplus heat from the plant, and others when additional peak heat is required".

INTERIM OBSERVATIONS OF SYSTEM PERFORMANCE (February 1983)

After 3 months of operation, the systems were working more efficiently than was anticipated. During these early stages, many parties kept a close watch on operation and the general opinion was one of complete satisfaction.

NCPC reported no problems, and indicated that the generators' engine operating temperature was being maintained at a satisfactory 80° C with flue gas temperature fairly steady at 210° C. The exhaust recovery unit helped to dampen the noise transfer from the generators to outside, and the engine noise was almost inaudible when standing outside the NCPC enclosure.

The school was designed to operate at a water supply temperature of 62° C. However, on a winter visit, when the outdoor temperature was -24° C, the boilers were not operating and the building appeared very comfortable at a water supply temperature of 60° C.

From the period of initial operation of the school heating system on September 20, 1982 until the end of the year, the system was "on trial". Various parties were concerned that the optimum balance between the available NCPC waste heat and the school heating requirements should be obtained. As a result the system controls were continuously altered to attempt to find the best settings. Initially, the building was heated using only the jacket water exchanger and this provided 100% of the heat up to the end of November.

It was not until January 1983, when the school classes were gradually being transferred to the new school, that the heating system could be accurately monitored, with both the jacket water and exhaust recovery operating.

A site visit was made on January 7, 1983 and the school's maintenance engineer was asked to begin taking daily readings as his duties permitted. Table 1 shows the information that was recorded from within the school boiler room.

Readings taken during this visit also enabled the engineers to begin evaluating the system over the future months.

7.0

ANALYSIS

7.0 ANALYSIS

The electrical load of the town's generators, together with the school's heat requirements, are constantly changing throughout the day and the year.

It was found that the NCPC load, and the school heat requirements, are in phase despite all the variables which have to be considered. As the outside temperature falls, NCPC waste heat increases at a similar rate to the school heating load. As the temperature rises, the opposite occurs.

The actual quantity of heat supply and demand are very well matched, particularly in the winter months when this is most important. It appears that for much of the time, the total heat given up by the NCPC engines was used by the school. Only very rarely was the demand higher than the available heat supply, and it was only at those times that the school boilers were required to operate.

WINTER OPERATION OF HEAT RECOVERY SYSTEM

As mentioned before, during one of our winter visits, it was detected that the NCPC radiator was cold and we made the assumption that the total waste heat was being given up to the school. In other words, at an outside temperature of -24° C, 100% of NCPC's waste heat is recovered by the school at 66% generator load.

From the readings, the heat recovered from the generators is as follows:

Q = m x s x dt
Jacket Water = 2.11 x 4.18 x 10 = 88.2 KW
Exhaust Gases = 2.11 x 4.18 x 5 = 44.1 KW
Total Heat Recovered =132.3 KW

There are obviously some line losses between the NCPC plant and the school as the pipes pass underground for approximately 100 metres. However, the losses are so small that the meters cannot detect them. By calculation we predict the total loss from the interconnecting pipes to be approximately 3 KW.

The relevant information is therefore:

Generator Electrical Output = 100 KW
Total Heat Recovered = 132.3 KW
Outside Temperature = -24°C

We have assumed that 100% of the heat output is being recovered, therefore it can be said that:

> For every 1 KW of generator electrical output, 1.32 KW of recoverable waste heat is produced.

From this statement, the quantity of recoverable heat can be ascertained from the predictions of monthly electrical output. The interim predictions of electrical output and recoverable heat and the associated relationships, are tabulated in Table 2.

The total generator output for January 1983 was 53,325 KWH (as recorded by NCPC).

Using an "1.32 KW heat output per 1.0 KW load" equation.

January waste heat available = 53,325 x 1.32
= 70,389 KWH

From our readings over the period January 7 to January 31, 1983 (see Table 1) the energy input into the school from the NCPC plant was:

206.06 - 157.19 MWH = 48,870 KWH.

For this period there were 1105 degree days, and we shall use this figure to get an approximation of the January school heating load.

$$\text{January school load} = 48{,}870 \times \frac{1{,}371}{1{,}105}$$
$$= 60{,}634 \text{ KWH}$$

Where the number of degree days in January was 1,371.

So our estimates for January are:

Generator heat output = 70,389 KWH
School heat requirements = 60,634 KWH

The figures tell us that basically the waste heat from the generators is adequate for the school. We know from our observations that there is an excess waste heat at night, which accounts for the difference in figures. However, we must not discount the possibility that there are occasional times when, during an extremely cold spell, the generator heat is not sufficient to totally heat the school (although there is no firm evidence to date that the boilers have been required to fire, to make up the water supply temperature).

SUMMER OPERATION OF HEAT RECOVERY SYSTEM

The school heat requirements over the summer months, shown in Table 4, are significantly higher than had been predicted. The major reason for this is the fact that the ventilation equipment has been used to a much larger extent over the summer months than had been anticipated. It was assumed that the ventilation fans would be switched off during the school summer break and so the school heat demand would be very light.

It appears that the school is being used for various other activities in the summer and the fans are generally kept on their automatic mode (that is, continuous daytime use). During one of the summer inspections, when the outdoor temperature was 15° C, the ventilation system certainly worked well in preventing a heat build-up within the school.

The ventilation controls are designed so that when the outdoor temperature rises above a certain setpoint, the fresh air damper opens to 100% position, to make use of as much free cooling as possible, when required. The total air quantity, however, of 7.2 cu. m./sec., imposes a sizeable heating load on the air coil, if ever the outdoor air temperature falls just a few degrees. This heating load is apparent in Table 4, and was not anticipated at the design stage.

If it was wished to decrease the school's ventilation heating load in the summer, it would be simply a matter of adjusting the setpoint of the outdoor air temperature sensor. If it is intended to operate the fans in the summer, however, then the dissipation of the heat in the coil is a bonus. This heat is the excess heat from the NCPC plant and the radiators would normally be required to reject it to atmosphere.

8.0

LIMITATIONS OF THE ANALYSIS

8.0 LIMITATIONS OF ANALYSIS (An interim collection of comments concerning the Analysis-February 1983

If the only concern of the project is the amount of financial saving which come about from the school's decreased oil consumption, then at the end of the first year an accurate figure of fuel saved and hence financial savings shall be available, and shall give that information.

However if the results of this project are going to help determine the designs and control systems of future heat recovery projects, then we need to try and understand exactly what is happening during different times of the year and at different outside temperatures.

The more readings that can be taken, particularly during the winter months when the NCPC waste heat cannot always supply enough heat, the more accurate are the assumptions as to how the system is behaving. Unless somebody is taking readings 24 hours a day, then these assumptions must be made.

The heat equation, Q=m.s.dt, shows that the school Heat Load is proportional to the difference between the inside and outside temperatures (dt). As we like to keep the inside temperature constant, we can say that the school heat load is proportional to the outside temperature. So now all we need are a few readings of the school load at various outside temperatures, in order to obtain an accurate picture of the school's behaviour at varying outside conditions.

It must be remembered that "night setback" is incorporated into the school's heating design and it is during the night as the outside temperature falls and the generators' output fall, that predictions must be made.

The community's generators' electrical load, and therefore their waste heat output, is not so predictable as the school's heat load.

The generators' load is constantly varying, during the day, during the night, and over the whole year. During the day, peaks occur at early morning and early evening when there maximum cooking, washing, etc. The load also increases darkness falls, which occurs at a different time each day. Also the generators' load changes as the outside temperat varies, although this is not as linear relationship as the case for the school.

So it can be seen that although the school heating load is relatively easy to predict, the heat available from the generator plant is less easy to foresee. NCPC shall provide the year's electrical loads at the end of the year, thus allowing us to calculate the waste heat outputs available.

One other point which has to be taken into account concerns "degree days". For a particular day, the number of degree days is the difference between the average temperature for that day, in degrees celsius, and a base temperature (18°C). For example, if the average temperature one day was -20°C, then it is said there were 38 degree days for that day.

An accurate set of figures of degree days can be gathered for the year. However, it must be remembered that the figure is based on the average outside temperature and it does not tell us how the temperatue varied when it fell below that average value. We would need to know the full set of temperatures during the day and night in order to predict how the heat recovery system performed. As this is obviously too impractical, assumptions and guesses must be made.

Having listed the limitations of the readings and the consequent assumptions that must be made, it must be said that by the end of the first year, when all readings have been gathered and visual accounts are available from site visits, the analysis will provide an accurate account of the heat recovery systems's operation.

CONCLUSIONS - August 1983

Now that the data for the whole heating season are available, we can see that many of our concerns regarding the inaccuracy of the results are unfounded. Despite our lack of data at precise times of day and night, we are still able to obtain an accurate picture of the operation. The general observation that the generator heat output and school demand are in phase with one another is the most important factor.

9.0

ENERGY SAVINGS ANALYSIS

9.0 ENERGY SAVINGS ANALYSIS

We can now look at the energy savings predictions made at the beginning of the project and compare them with what actually happened over the first heating season.

As previously stated, no oil was transferred to the day tank from the main school storage tank, throughout the whole winter. The only oil that was used was some of that originally contained in the day tank.

On January 7th, 1983 the oil level was 850 litres.
On July 7th, 1983 the oil level was 480 litres.

So the annual oil consumption for the school was only 370 litres.

Due to the lack of use of the school boilers, the school maintenance engineer was asked to operate them each weekend, in order to check their working condition. According to the engineer, the only other times that the boilers were seen to fire was when the outdoor temperature dropped to the high -30° C's.

The unexpected use of the ventilation equipment in the summer and the associated pump operation, was an added cost but unrelated to the heat recovery system costs.

Tables 1-5 give data, interim predictions and our up-to-date calculations.

UPDATED FINANCIAL SAVINGS - August 16, 1983

Cost to Heat Building Using Only Boilers Without Combined Waste Heat Recovery

Fuel oil required: 50,150 litres/year (88% of original estimate)	
@ $0.580/litre	$29,087
Boiler operating time: 2,658 hours @ 0.25 KW = 665 KWH @ $0.573	$ 381
Oil transfer pumps: 160 hours @ 0.5 KW = 80 KWH @ $0.573	$ 46
Total Heating Costs (Incl. Electrical Power)	$29,514

Energy Efficient Alternative: using NCPC waste heat

Fuel oil required: 370 litres/year @ $0.580/litre	$ 215
Boiler electrical and transfer pumps: 6 KWH @ $0.573	$ 3
Recirculating pump: 0.56 KW for 365 days = 4,906 KWH @ $0.573	$ 2,811
Total Cost Using Waste Heat	$ 3,029

Therefore: Net savings are:

29,541 - $3,029 = $26,485 /annum

This compares with a predicted figure of $18,854/annum.

NCPC have waived the 50% charge on waste heat, so the full saving can now be realized by GNWT.

In the financial evaluation if must also be noted that the final cost of the heat recovery equipment and installation was $249,000 compared with the $60,000 initial input.

10.0

CONCLUSIONS

10.0 CONCLUSIONS

1. Now that the school has operated through a whole winter season, the project can be considered a success to this point. NCPC are reporting no problems; the design consultants are pleased with the system operation and the community and GNWT are benefiting from the low fuel usage of the school.

2. The recoverable heat from the generating equipment appears to be approximately 10% larger than anticipated. Considering this, and the fact that the school loads are only 60% of what was initially calculated, NCPC's waste heat is almost totally satisfying the school's heat requirements.

3. Payback period is approximately 9 years. This is higher than had been anticipated due to the final capital cost of the heat recovery system being nearly 400% higher than was first thought. Another factor is the fuel inflation rate which has dropped from previous values.

11.0

RECOMMENDATIONS

11.0 RECOMMENDATIONS

The project was designed, installed and is now operating without any major hitches, and so there are very few unforeseen problems that need to be documented. We feel the following points should be noted.

1. One of the major reasons for the success of this project, was the co-operation shown between all parties throughout the job. It should not be underestimated how this can improve all stages of the project.

2. We feel that it is important that NCPC design and install their portion of the work. Only they know what future space requirements they have in their generating buildings. Their knowledge of the equipment and the fact that they would be responsible for future maintenance makes it important that they control all of the in-plant work.

3. A problem that developed in a similar installation in Igloolik should be noted (see Section 12.0). The glycol level within the secondary system should be checked at least once every year, to ensure the concentration never falls below 50%.

12.0

IGLOOLIK HEAT RECOVERY

12.0 IGLOOLIK HEAT RECOVERY

There is much attention now being paid to the possibilities of using NCPC's waste heat in many of the communities across Canada. We are developing the expertise for designing, estimating and installing the heat recovery systems. Lac La Martre provided the opportunity to develop that expertise still further.

In the past, however, some of the installations have not run as smoothly and Igloolik is one example that highlights the importance of a well-thought out system design.

The Igloolik heat recovery was installed in the mid-1970's. The NCPC plant is connected to some of the Hamlet buildings via a heat exchanger, whereby the heat contained within the generator motors' jacket water is used for heating purposes in the Hamlet.

In the summer of 1982, NCPC in Frobisher Bay was informed of problems developing in the Igloolik system. The secondary circuit expansion tank, positioned at the suction of the secondary pump, was continuously draining, while that on the primary (jacket water) circuit was overflowing.

The two systems meet at the tube and shell heat exchanger so a rupture of one of the tubes was suspected. The secondary loop, that ran from NCPC to the Hamlet, operated at a higher pressure than that of the primary, which explained why the secondary expansion tank was draining and the primary tank was overflowing.

NCPC advised that the complete secondary side of the system be shut off and they isolated the heat exchanger from the generator motors' jacket water circuit.

The maintenance engineer, who flew in from Frobisher Bay, found that the plate holding the bundles together within the exchanger, had separated from the tubes, forming an opening.

The general opinion as to the cause of the failure, was that the secondary system was run either without glycol, or the glycol level had decreased to such a low percentage over the years that freezing occurred. When a pipe freezes the point of greatest pressure is at that part of the system that is the last to freeze. In this case the heat exchanger would have received enormous water pressures from the expansion of the frozen water within the piping further down the system.

In such an isolated community, the systems have to be almost completely "freeze-proof" because a relatively minor leak can cause enormous problems in getting replacement parts and having to do repair work in freezing conditions.

Once the leak had been detected there was confusion as to whose responsibility it was to make the necessary repairs. Both the Hamlet and NCPC claimed it was the others responsibility. Nothing was done until the second tube bundle failed later in the same winter and the Hamlet approached the GNWT to redesign and repair the system.

The system was redesigned and a new contract signed with NCPC whereby the Hamlet receives free heat but becomes totally responsible for the secondary system including the heat exchanger.

It is now NCPC's general policy that their responsibility lies only on the primary side of the system up to the flanges of the heat exchanger.

13.0

N.C.P.C. SUMMARY OF N.W.T. SYSTEMS

NORTHERN
CANADA
POWER
COMMISSION

COMMISSION
D'ENERGIE
DU NORD
CANADIEN

1815 (LM)

1983 08 03

Government of the Northwest Territories
Department of Public Works
Energy Conservation Division
YELLOWKNIFE, N.W.T.
X1A 2L9

Attention: J.A. Severn

Dear Sir:

Re: Engine and Exhaust Heat Recovery

The Commission have been recovering rejected heat from diesel generating units for many years at a large number of plants.

At Whitehorse, for example, jacket water heat recovery has been set up since 1970 and used when the connected engines are in service. The recovered heat is used to warm the engine fuel and keep the hydro plant dyke from freezing and heaving in winter. Since the units here are on standby service this secondary system has a boiler in series to make up the needed heat when the engines are not in service. The total number of engines involved is three with a total kW rating of 13,940. The recovered engine heat is only a portion of the total which is available from this operating machinery but is sufficient for the purpose needed.

Similarly the Baker Lake old plant is equipped for jacket heat recovery and this heat is used simply to warm the old plant when this machinery operates. In a similar fashion, many of our northern plants are equipped with jacket heat recovery for the purpose of plant garage and warehouse heating. Such systems have been in service 10 to 20 years with good success.

Over the last 6 or 7 years the GNWT have shown an interest in diesel plant available rejected heat energy. We designed and constructed the system of jacket recovery at Cambridge Bay in 1978 as an arrangement to provide heat to GNWT warehouses and shops in this community. This system, having proven its effectiveness, resulted in GNWT asking us to install jacket and exhaust heat recovery in Pelly Bay and Lac La Martre. These systems

...../2

too have proven to be very successful and financially rewarding to the user.

The design construction role of NCPC is within the plant. From the plant outward the user constructs the insulated pipe lines and circulates the necessary secondary coolant.

The aim of the NCPC designers is to construct a system in the plant that does not interfere with access to the machinery and does not impose hardships of any sort on the machinery.

Frankly we as NCPC designers and engineers like jacket heat recovery as it absorbs machinery heat which would otherwise have to be directed to the radiators and cooled by operating radiator fans. Since about 5 h.p. of electric motor fan power is required for every 300 kW of engine generated power this wasted fan energy can be saved to the cost benefit of NCPC.

As a further example, our Cambridge Bay plant presently has one unit radiator for two 720 kW units. Normally one of these generating units operates at one time so there is no cooling problem. In the spring of 1983 other units in this plant failed and as a result both the two 720 kW sets had to be operated together. It was only because of the added cooling ability of the heat recovery system that the plant was able to operate very successfully without engine overheating problems during this period.

The Rankin Inlet heat recovery arrangement is set up to recover jacket heat from any or all of three 720 kW units. This heat is used to heat GNWT offices and shops as well as domestic water. NCPC plant office/ warehouse heat is taken from a second exchanger in the same primary circuit.

The Igloolik arrangement is again jacket heat and again an exchanger arrangement extracts jacket heat. The secondary heat is used to heat a community building and a swimming pool as well as an NCPC garage.

The Dawson City plant arrangement collects heat from all or any of the five installed plant diesel generating units. This heat is used to raise the temperature of the town domestic water system.

The list attached provides the main installations where heat recovery for external purposes is set up.

Two major projects presently under study by GNWT, which have been discussed with us, are Fort Franklin and Pangnirtung. The final extent of these projects we do not know but we believe exhaust and jacket heat is being considered.

We trust this is what you require.

Yours truly,

D.I. McGuinness
Engineering Manager

DIM/jk

1165
1982 06 11
J. Allan
D.I. McGuinness
REJECTED "WASTE" HEAT RECOVERY

NCPC sites presently operational -

SITE	MODE OF RECOVERY	INSTALLATION DATE	APPROX. FINAL COST	APPROX. KILOJOULES PER HOUR REC.
Coppermine	jacket water	1976	$ 30,000	1,000,000
Rankin Inlet	jacket water	1979	47,500	2,500,000
Igloolik	jacket water	1978	30,000	750,000
Fort Simpson	jacket water	1979	22,500 (modification)	2,600,000
Cambridge Bay	jacket water	1978	(approx.) 47,000	2,000,000
Pelly Bay	jacket water	1981	120,000	500,000
Dawson *	jacket water	1967	-	2,500,000

1.05506 kilojoules - 1 BTU

* say $300 K - of revised recovery system being installed in June/82
Total capability of 7,500,000 kilojoules per hour. Completion July/82.

Sites presently completed and awaiting final commissioning - Pelly Bay. Project completed in March 1982. Jacket water and exhaust - cost $104,500. Total recoverable energy 2,250,000 kilojoules potential.

Sites presently in the process of completion - Lac La Martre (July/82). Jacket water and exhaust - cost $170,000. Total recoverable energy 860,000 kilojoules potential.

Sites at proposal stage - Broughton Island, Pangnirtung, Coppermine revamp.

Other sites where GNWT have shown some heat recovery interest - Spence Bay, Sachs Harbour, Pond Inlet, and Fort Franklin. Added recovery at Coppermine also under consideration.

Sites where some jacket recovery has been operational for many years to provide for "In Plant" heat recovery purposes - Whitehorse, Fort Norman, Fort Franklin, Fort Godd Hope, Gjoa Haven, Spence Bay, Pelly Bay, Broughton Island, Lac La Martre, Fort McPherson, Aklavik, Sachs Harbour, Holman Island, and Coppermine, Snowdrift, Rae Lakes, Pond Inlet, Clyde River, Pangnirtung, Cape Dorset, Lake Harbour, Resolute Bay, Arctic Bay, Baker Lake, Eskimo Point, Whale Cove, and Repulse Bay.

NOTES

Generalized rules of thumb for available heat recovery are as follows:

Jacket Water - 100% of available rejected energy can be recovered. The actual amount varies considerably depending upon the thermal characteristics of the engine design but as a rough figure about 2500 kilojoules per kW of engine output per hour can be assured to be recoverable.

Exhaust - Under engine full power the exhaust gas avilable heat energy is about equivalent to the jacket water available energy but realistic safe recovery can only be assured to be about 50% of that available.

Under these conditions some 1250 kilogoules per kW of engine output per hour can be assumed to be recoverable for heat usage.

Again the precise amount of exhaust gas heat recoverable depends upon the thermal aspects of the engine design of each particular engine and its utilization characteristics. These factors must be fully reviewed to enable precise judgements to be ascertained with accuracy. All in plant design work on projects to date have been carried out by NCPC staff.

ORIGINAL SIGNED BY
D. I. McGUINNESS

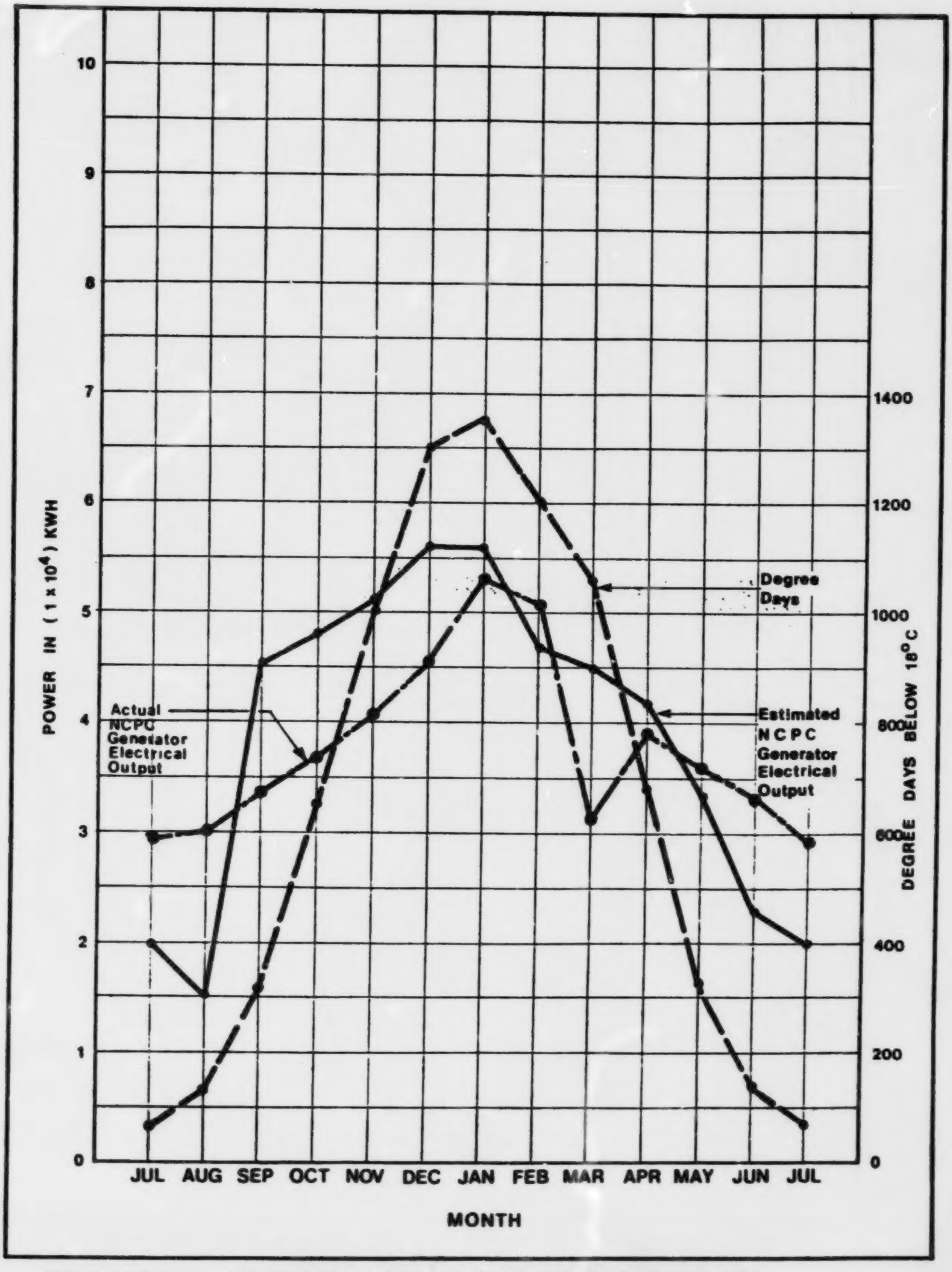
D.I. McGuinness

DIM/jk

APPENDICES

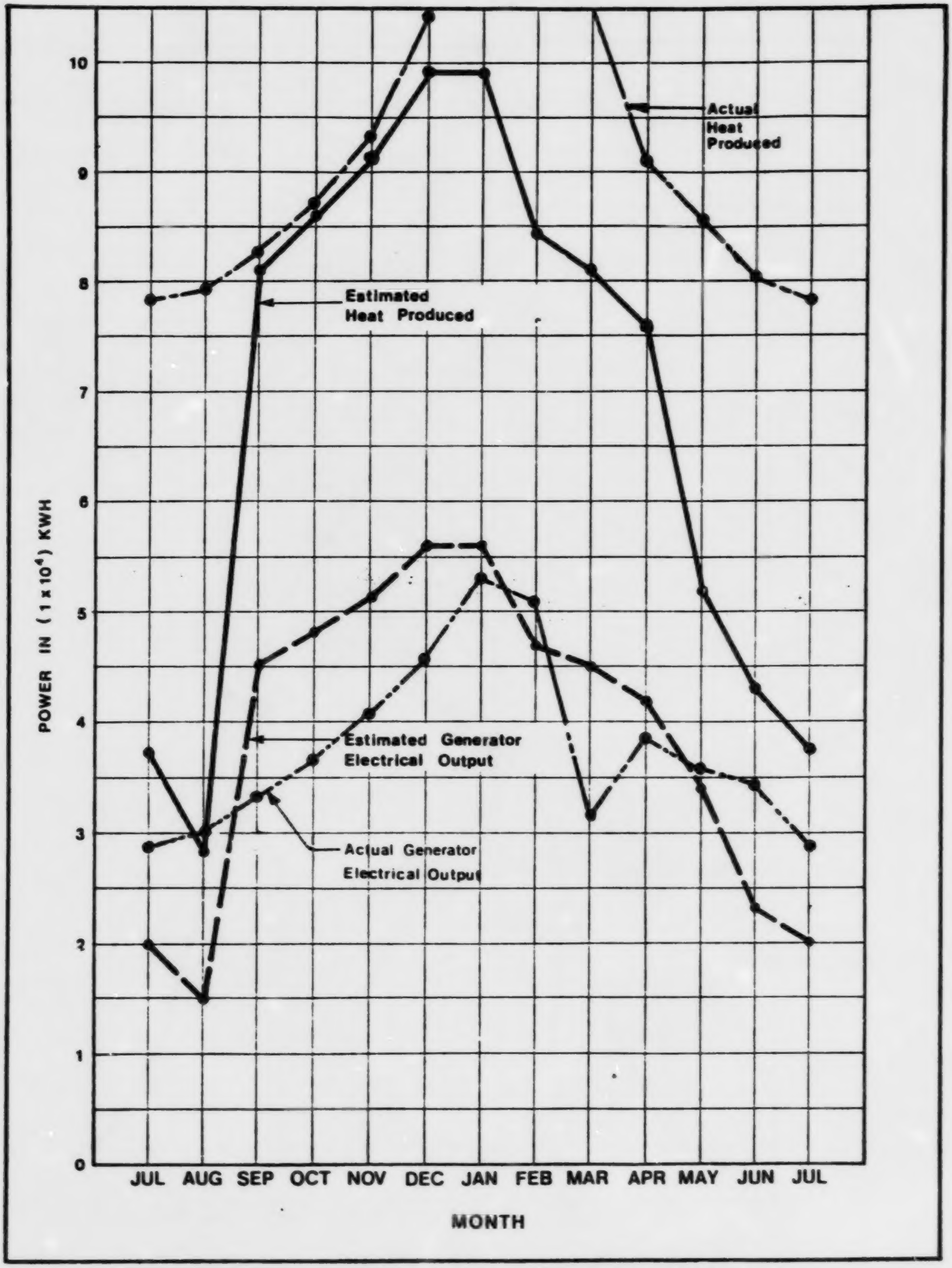
A.1

GRAPHS



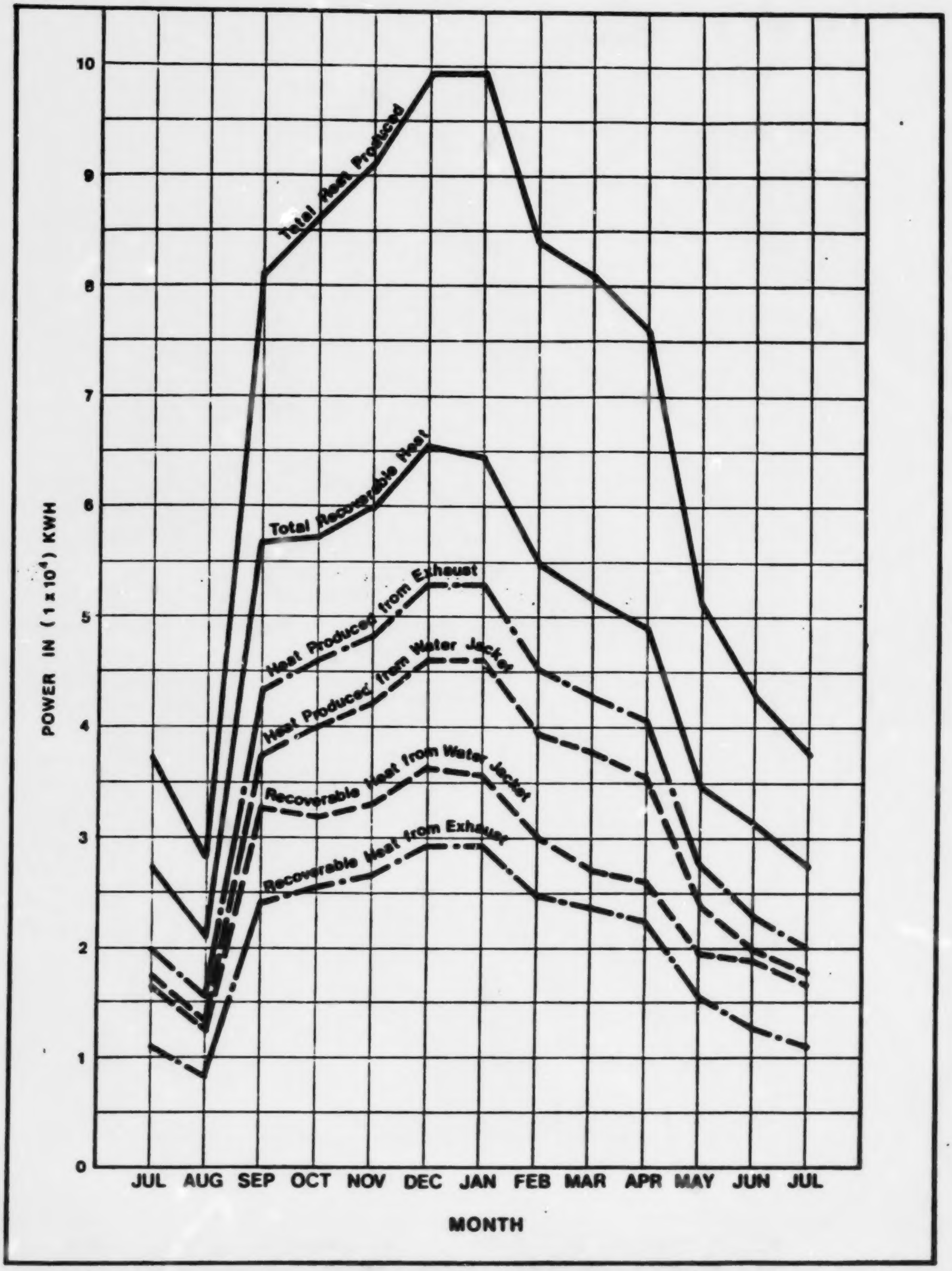
RELATIONSHIP BETWEEN LAC LA MARTRE DEGREE DAYS and N C P C ELECTRICAL OUTPUT

GRAPH 1



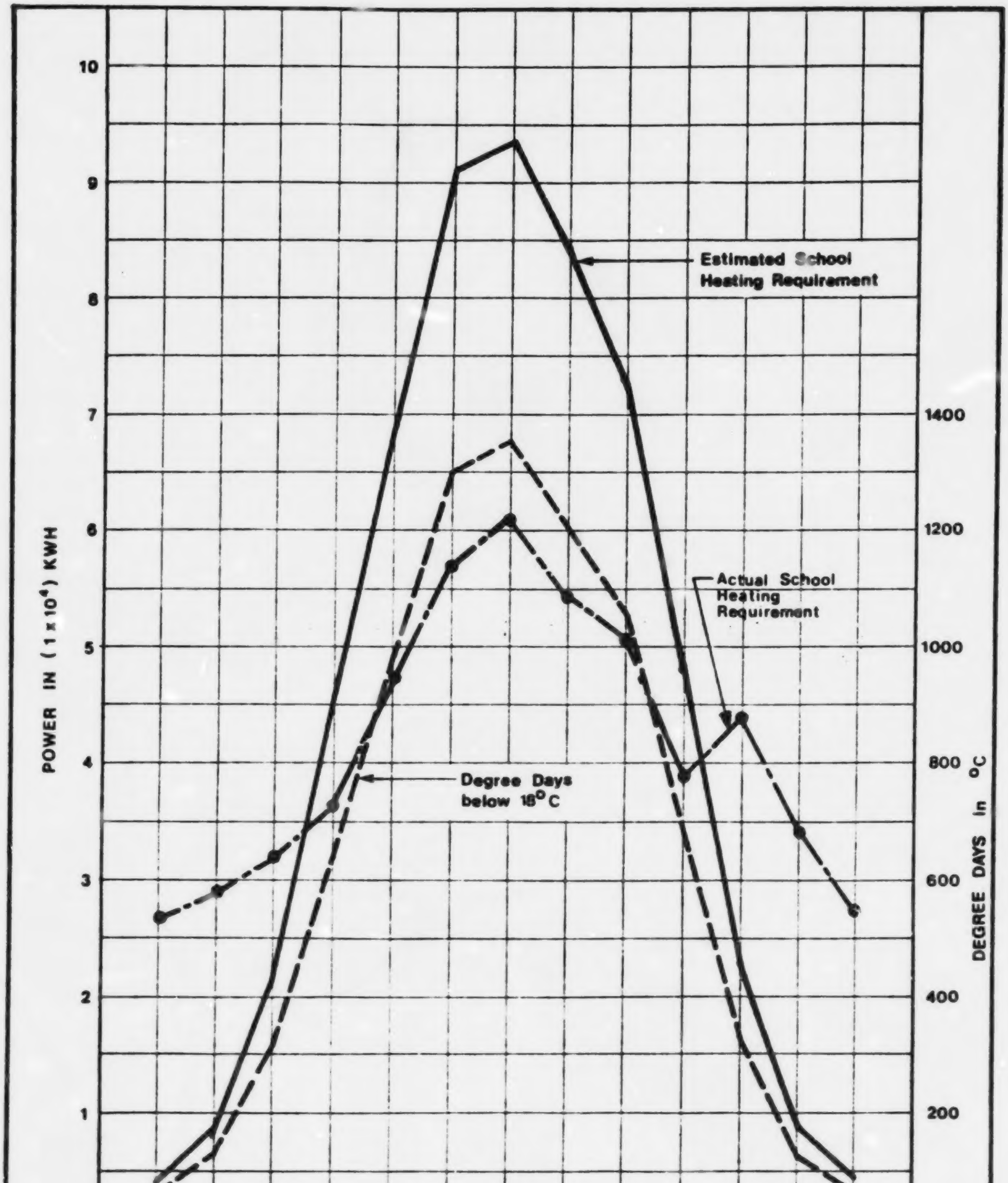
RELATIONSHIP BETWEEN NCPC GENERATOR OUTPUT and ITS SUBSEQUENT HEAT OUTPUT

GRAPH 2



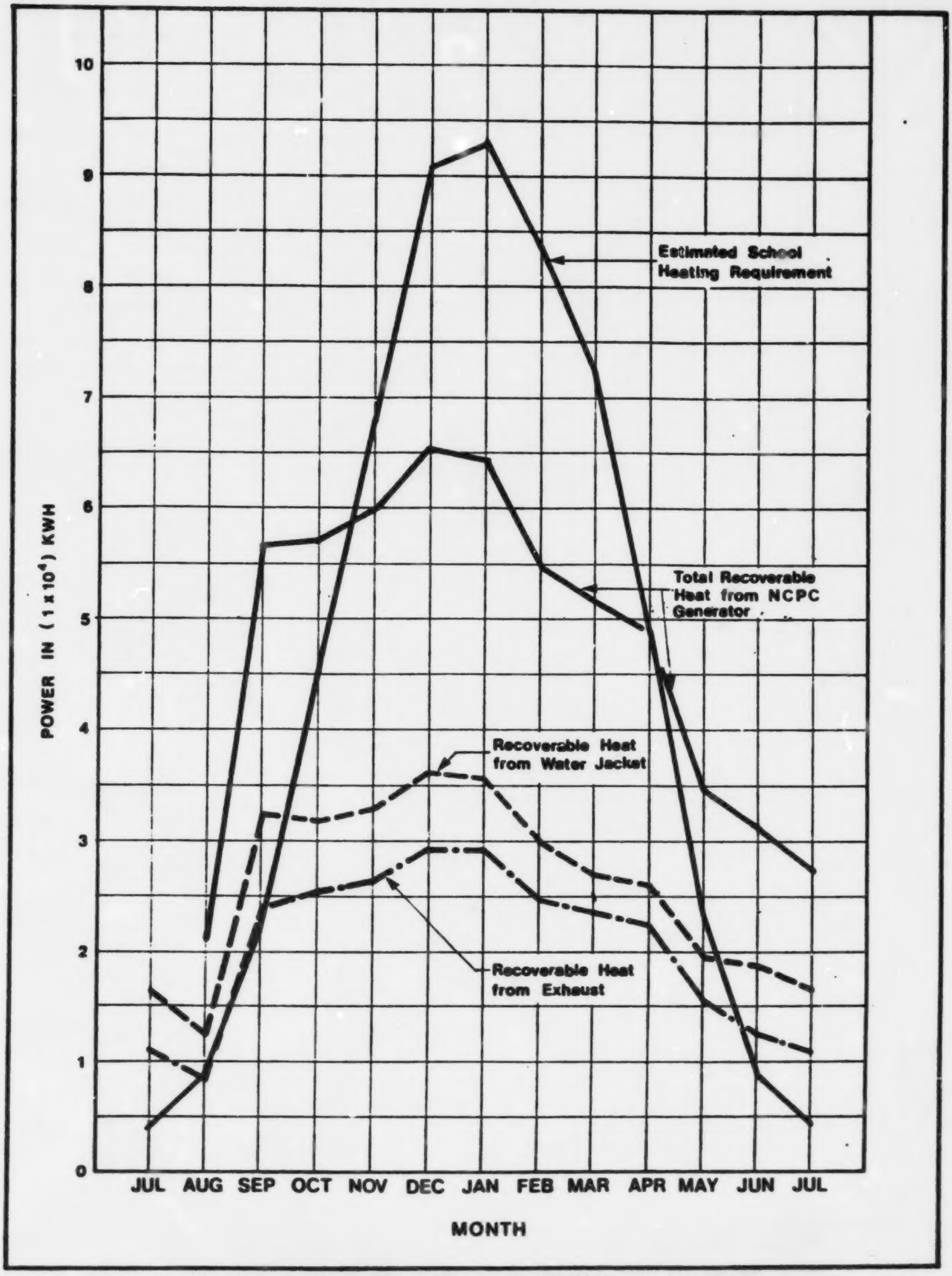
RELATIONSHIP BETWEEN GENERATOR HEAT PRODUCTION and RECOVERABLE HEAT (Estimated)

GRAPH 3



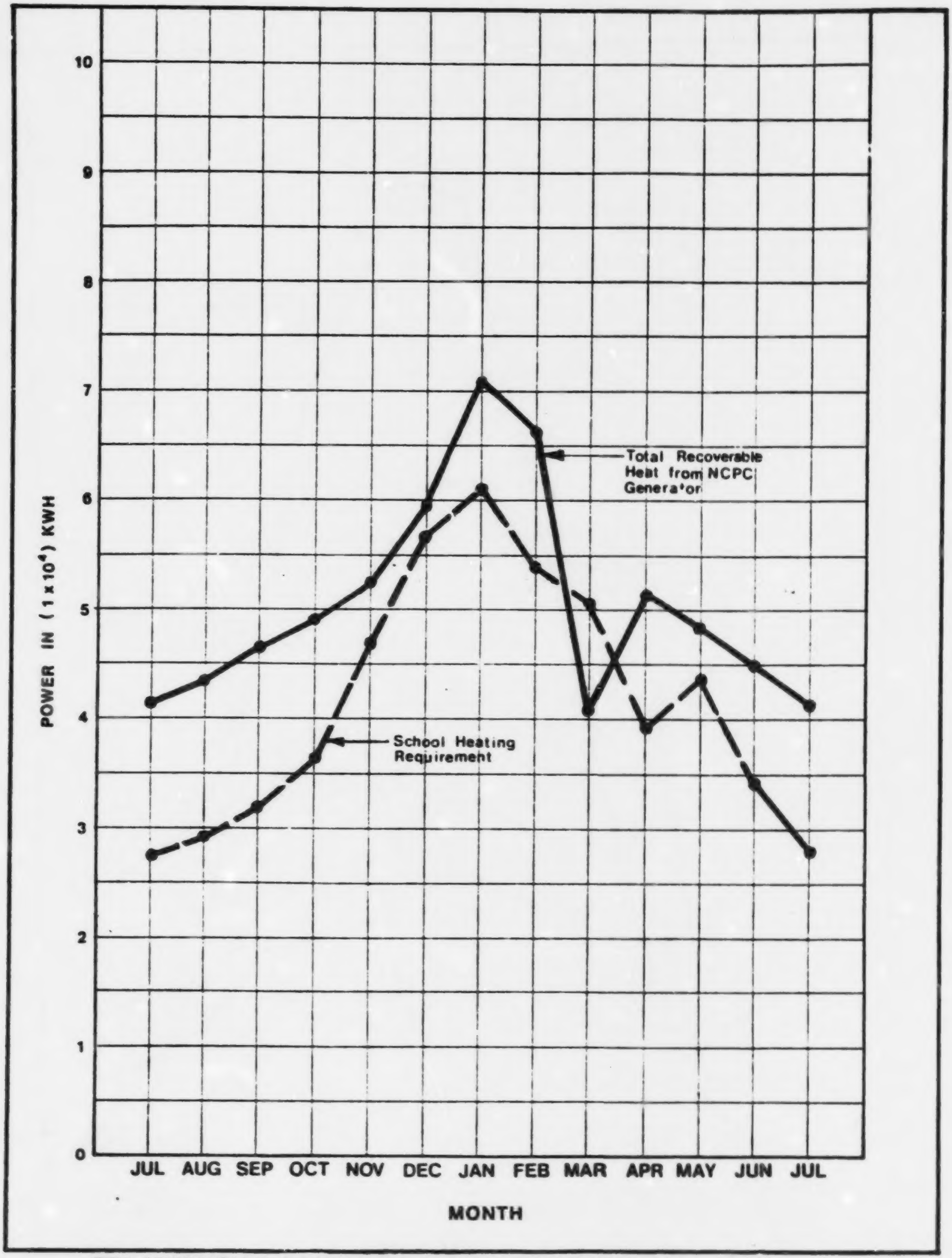
RELATIONSHIP BETWEEN LAC LA MARTRE DEGREE DAYS and SCHOOL HEATING REQUIREMENT

GRAPH 4



RELATIONSHIP BETWEEN NCPC RECOVERABLE HEAT and SCHOOL HEATING REQUIREMENT (Original Design Estimate)

GRAPH 5



RELATIONSHIP BETWEEN NCPC RECOVERABLE HEAT and SCHOOL HEATING REQUIREMENT (Actual)

GRAPH 6

A.2

FIGURES

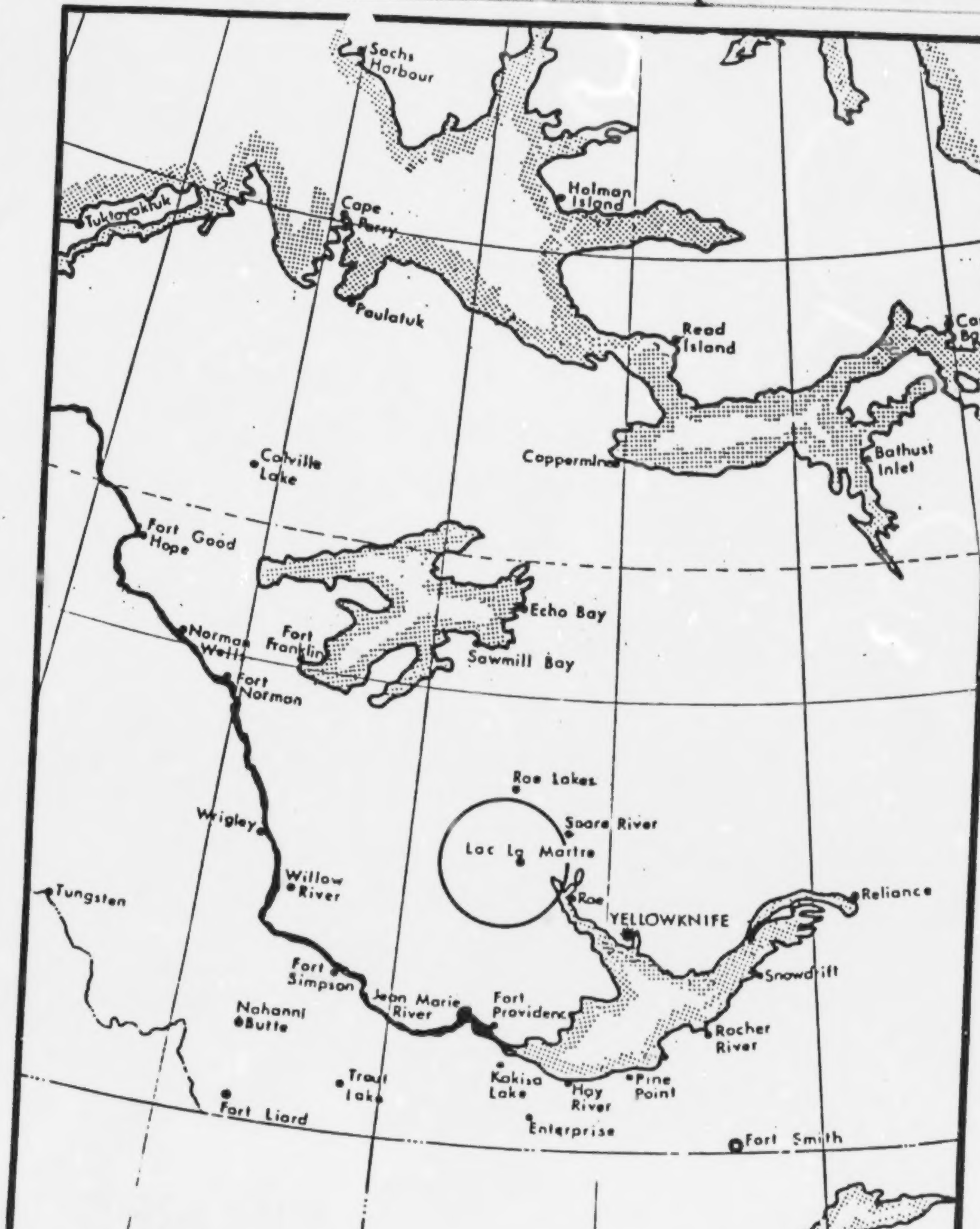
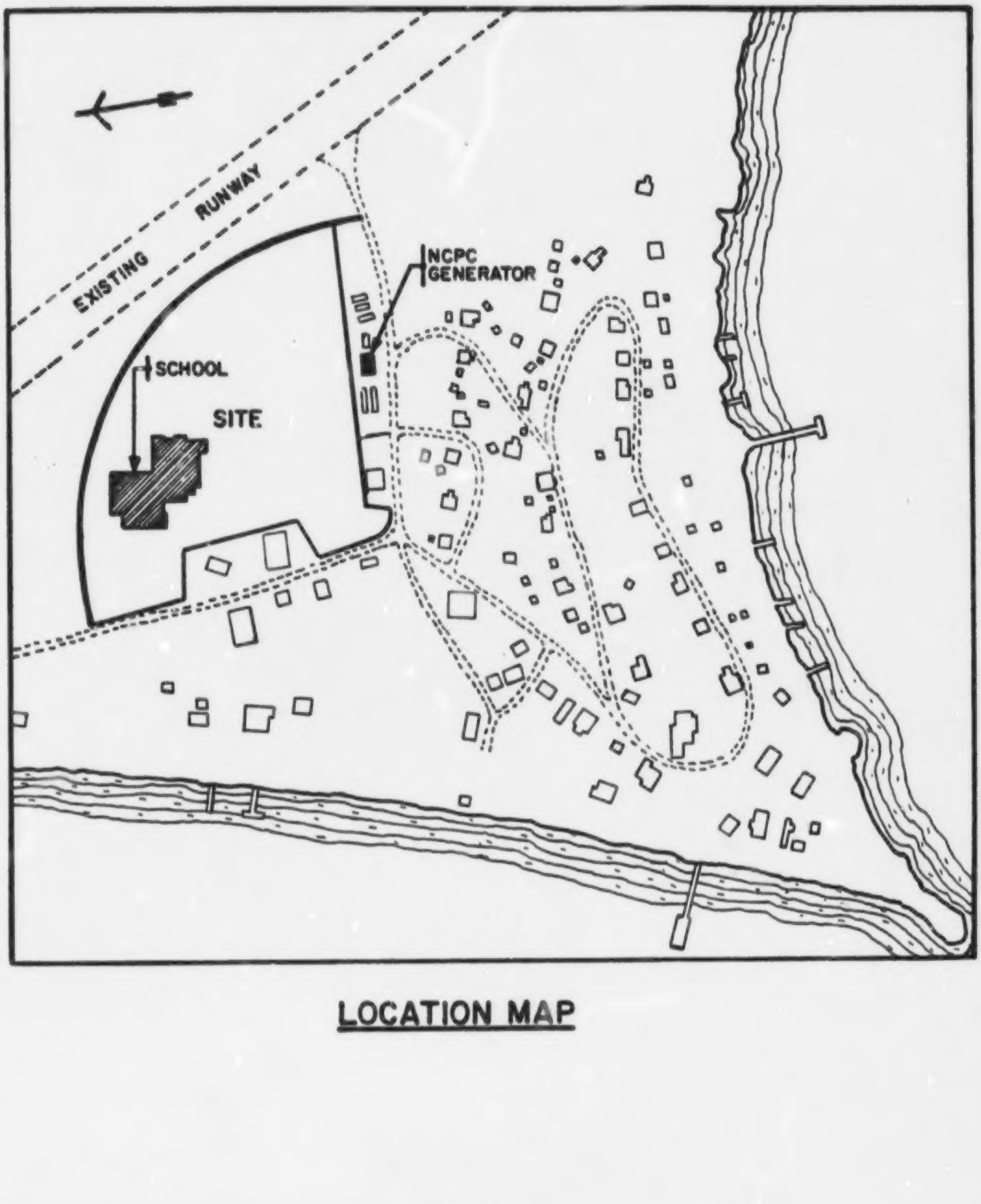
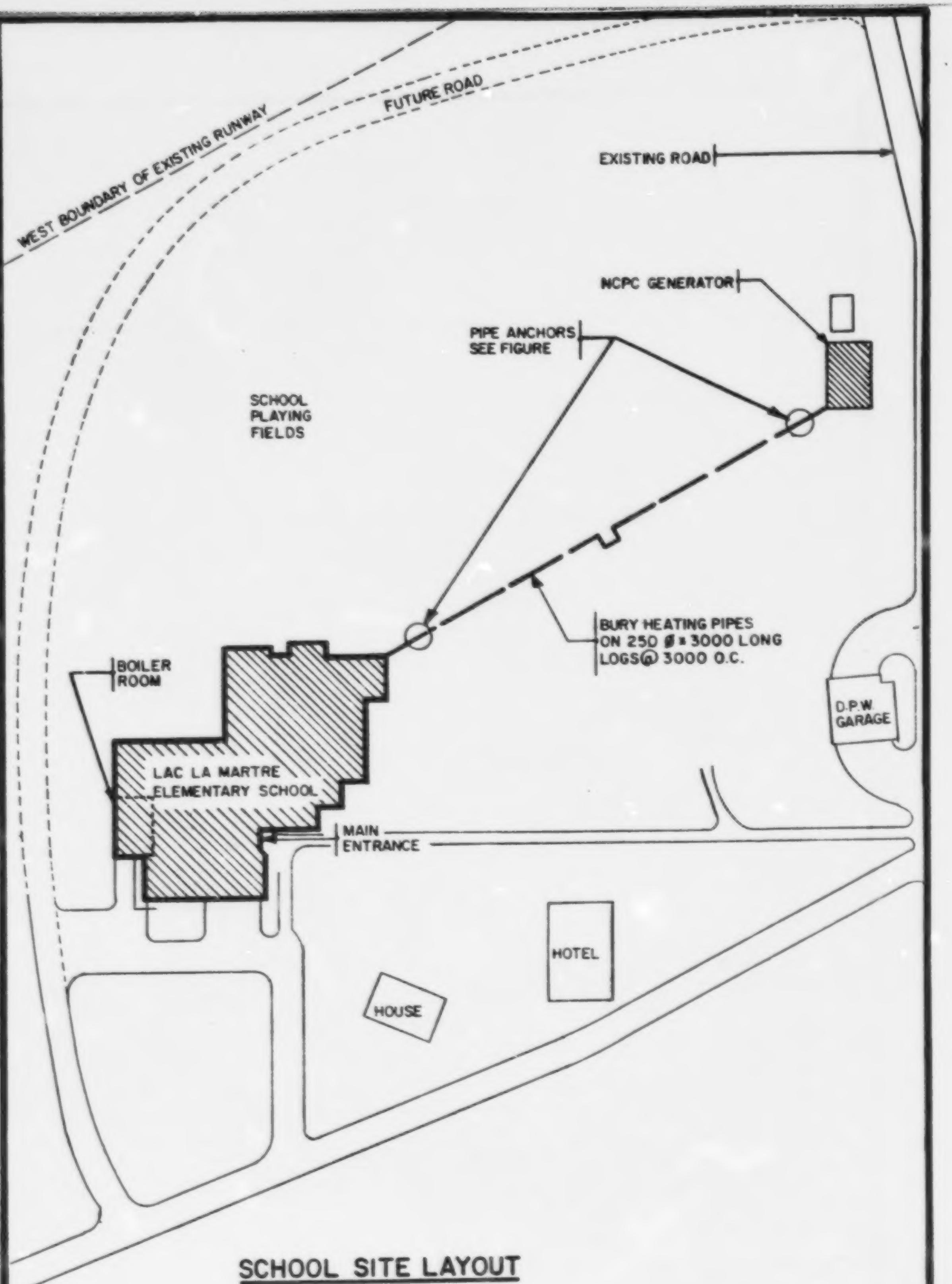

Sachs Harbour
Tuktoyaktuk
Cape Parry
Holman Island
Paulatuk
Read Island
Cam Bay
Coppermine
Bathust Inlet
Colville Lake
Fort Good Hope
Echo Bay
Norman Wells
Fort Franklin
Sawmill Bay
Fort Norman
Roe Lakes
Snare River
Lac La Martre
Wrigley
Willow River
Tungsten
Rae
YELLOWKNIFE
Reliance
Fort Simpson
Snowdrift
Jean Marie River
Fort Providence
Nahanni Butte
Rocher River
Trout Lake
Kakisa Lake
Hay River
Pine Point
Fort Liard
Enterprise
Fort Smith

FIG. I


EXISTING RUNWAY
NCPC GENERATOR
SCHOOL
SITE

LOCATION MAP

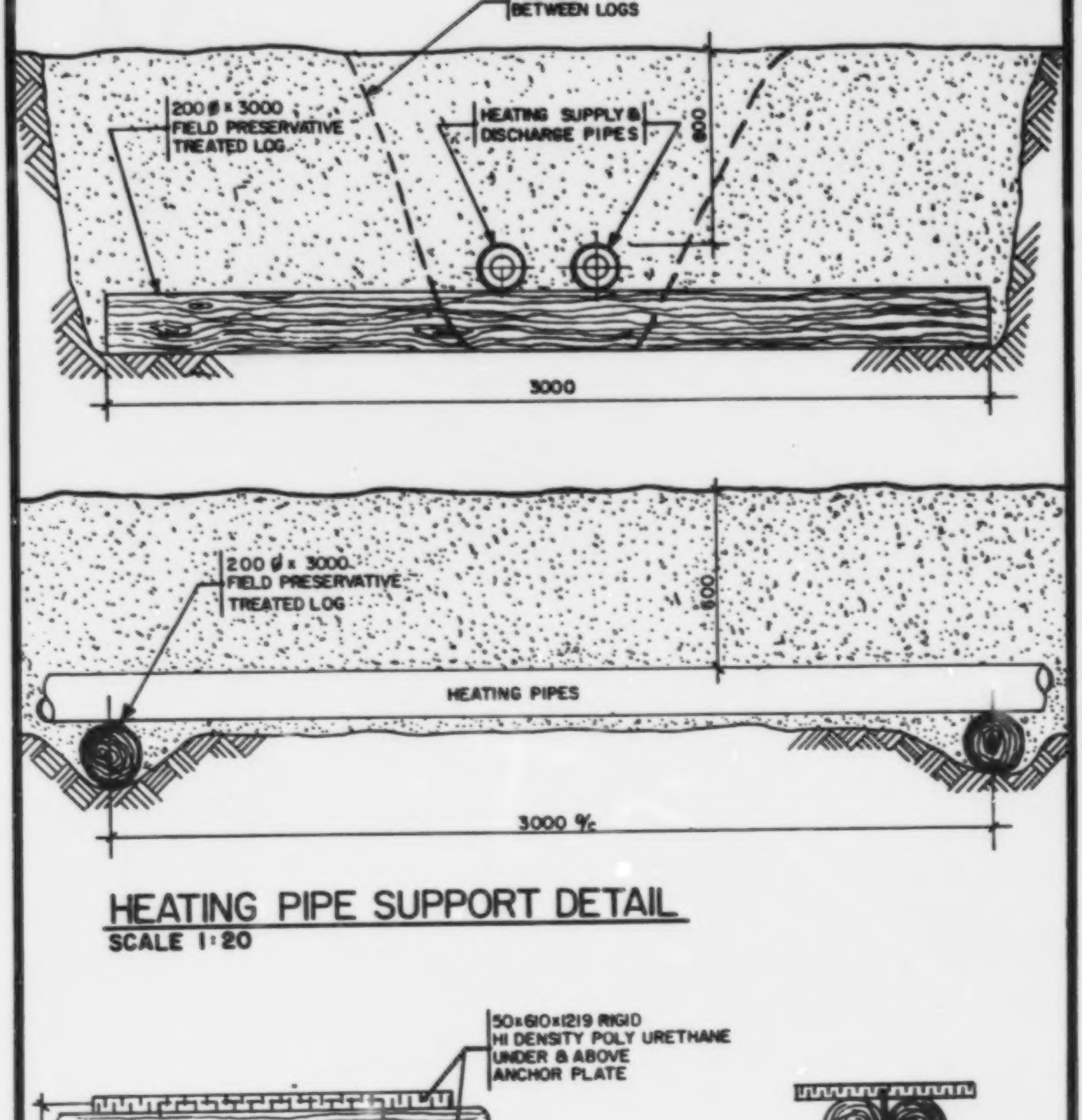
FIG. 2


WEST BOUNDARY OF EXISTING RUNWAY
FUTURE ROAD
EXISTING ROAD
NCPC GENERATOR
PIPE ANCHORS SEE FIGURE
SCHOOL PLAYING FIELDS
BURY HEATING PIPES ON 250 Ø x 3000 LONG LOGS @ 3000 O.C.
BOILER ROOM
LAC LA MARTRE ELEMENTARY SCHOOL
MAIN ENTRANCE
D.P.W. GARAGE
HOTEL
HOUSE

SCHOOL SITE LAYOUT

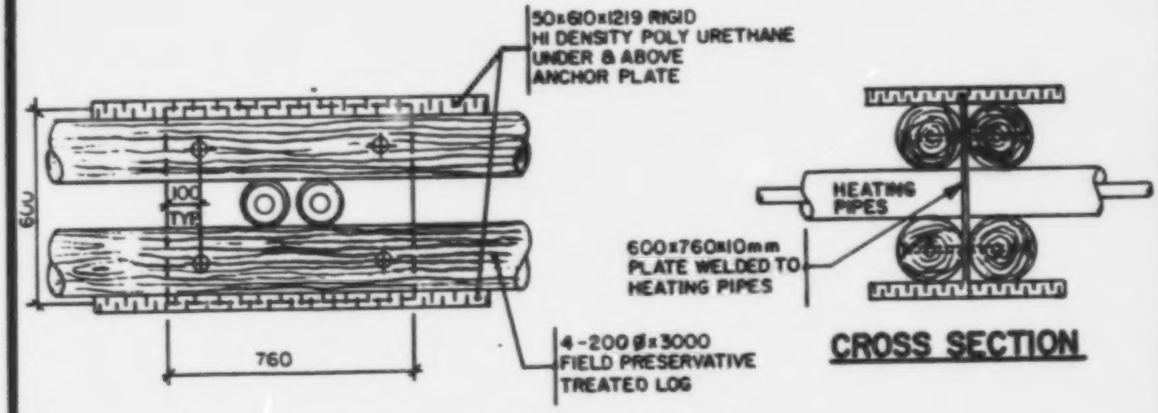
SCALE 1:1000

FIG. 3


TRENCH BETWEEN LOGS
200 Ø x 3000 FIELD PRESERVATIVE TREATED LOG
HEATING SUPPLY & DISCHARGE PIPES
600
3000
200 Ø x 3000 FIELD PRESERVATIVE TREATED LOG
600
HEATING PIPES
3000 %c

HEATING PIPE SUPPORT DETAIL

SCALE 1:20


50x610x1219 RIGID HI DENSITY POLY URETHANE UNDER & ABOVE ANCHOR PLATE
600
100 TYP
760
4-200 Ø x 3000 FIELD PRESERVATIVE TREATED LOG
HEATING PIPES
600x760x10mm PLATE WELDED TO HEATING PIPES

CROSS SECTION

HEATING PIPE ANCHOR DETAIL

SCALE 1:20

FIG.4

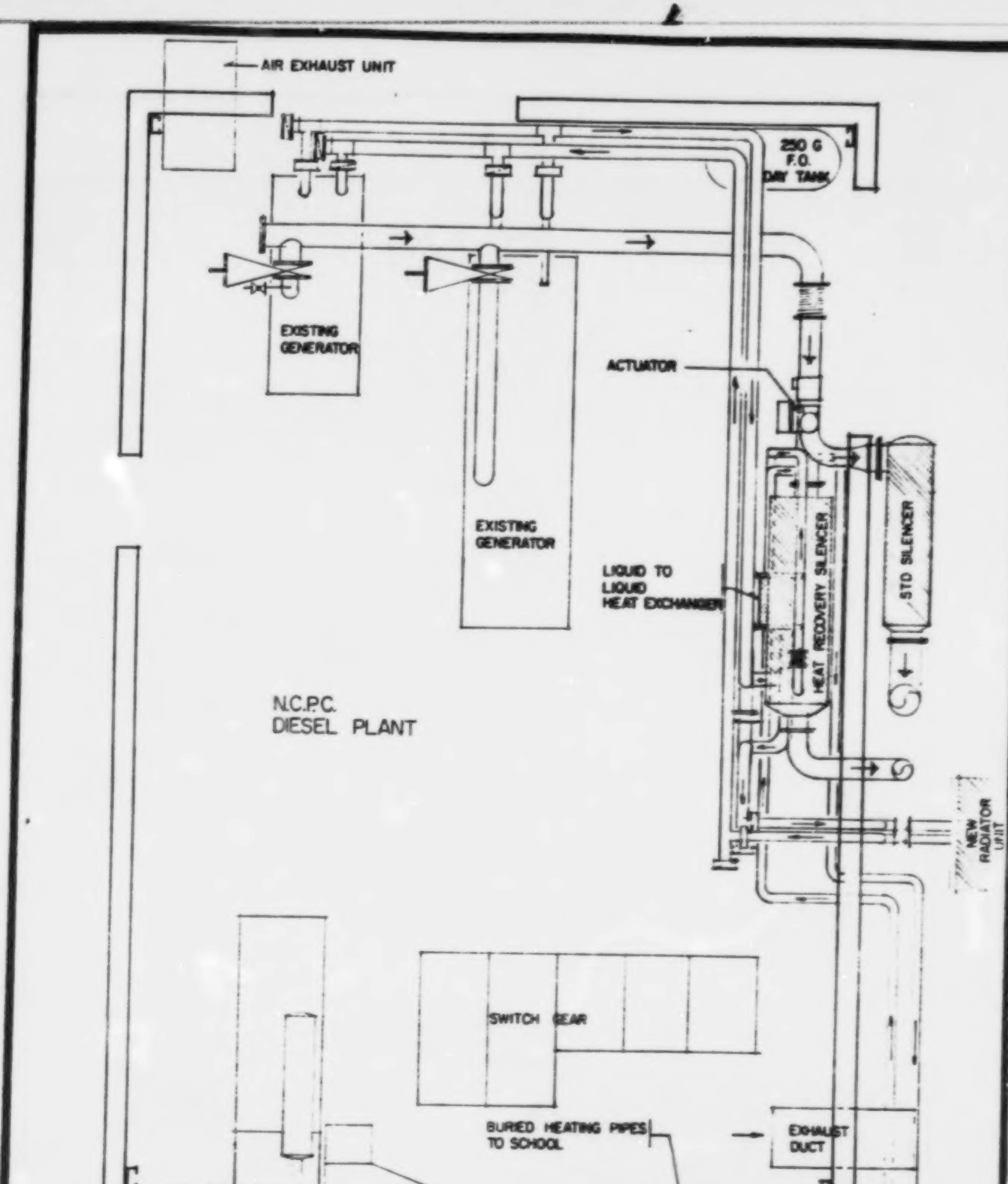
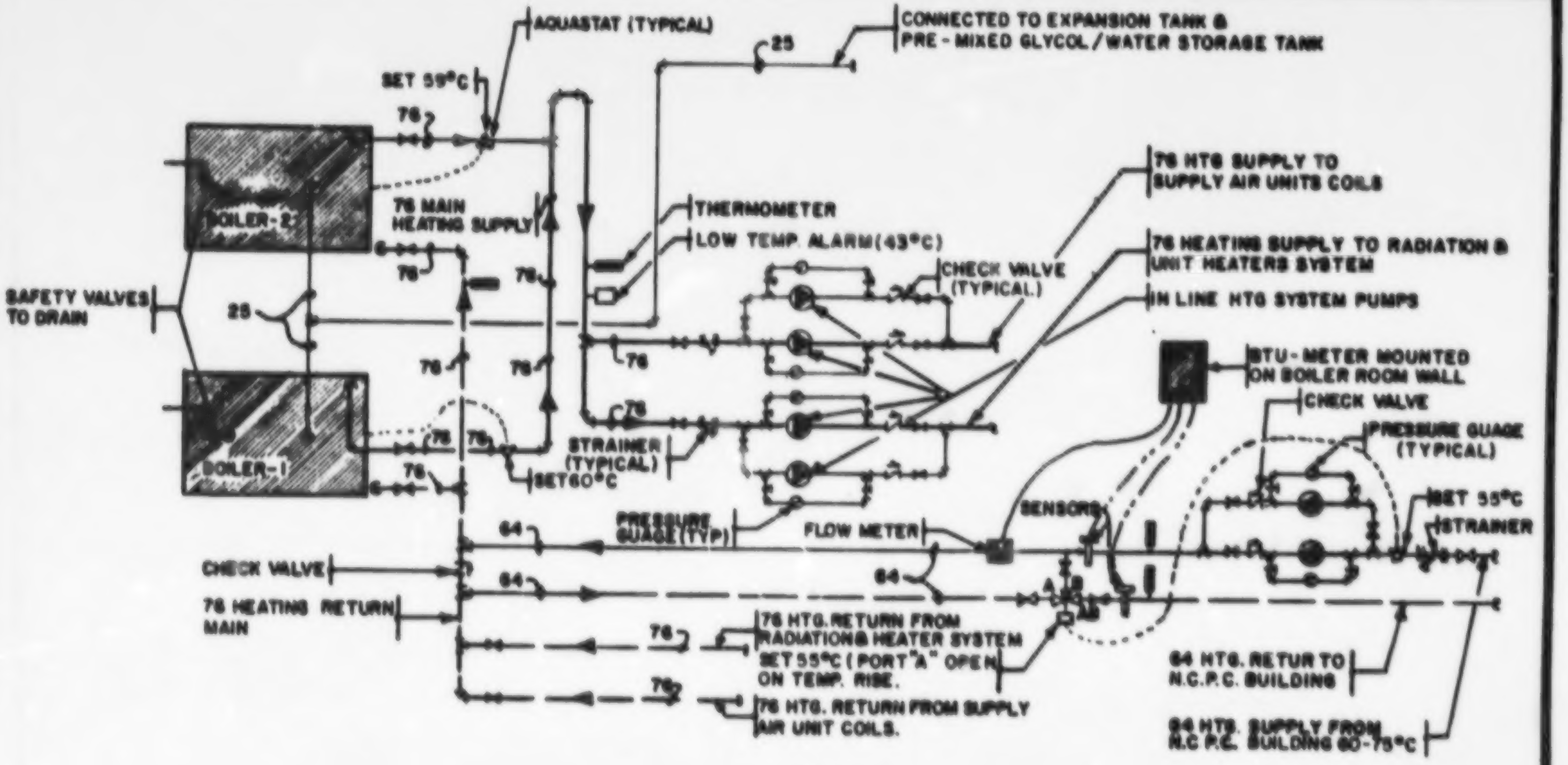
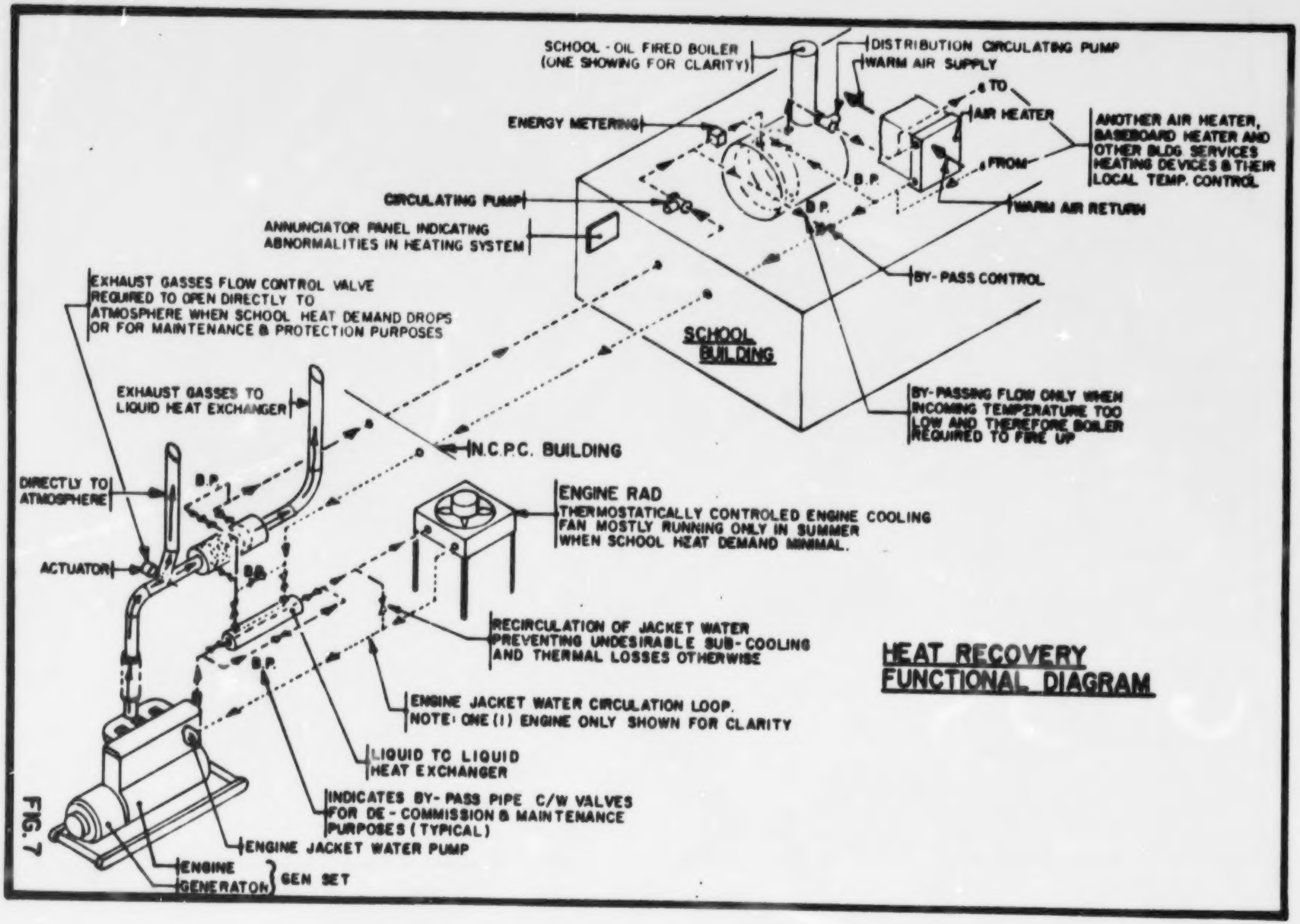

AIR EXHAUST UNIT
250 G
F.O.
DAY TANK
EXISTING GENERATOR
EXISTING GENERATOR
ACTUATOR
LIQUID TO
LIQUID
HEAT EXCHANGER
HEAT RECOVERY SILENCER
STD SILENCER
N.C.P.C.
DIESEL PLANT
NEW RADIATOR UNIT
SWITCH GEAR
BURIED HEATING PIPES
TO SCHOOL
EXHAUST DUCT
NEW AIR INTAKE

FIG. 5


AQUASTAT (TYPICAL)
SET 59°C
25
CONNECTED TO EXPANSION TANK & PRE - MIXED GLYCOL / WATER STORAGE TANK
76
BOILER-2
BOILER-1
76 MAIN HEATING SUPPLY
THERMOMETER
LOW TEMP. ALARM (43°C)
CHECK VALVE (TYPICAL)
76 HTG SUPPLY TO SUPPLY AIR UNITS COILS
76 HEATING SUPPLY TO RADIATION & UNIT HEATERS SYSTEM
IN LINE HTG SYSTEM PUMPS
SAFETY VALVES TO DRAIN
25
BTU - METER MOUNTED ON BOILER ROOM WALL
CHECK VALVE
PRESSURE GUAGE (TYPICAL)
STRAINER (TYPICAL)
SET 60°C
PRESSURE GUAGE (TYP)
FLOW METER
SENSORS
SET 55°C
STRAINER
64
CHECK VALVE
76 HEATING RETURN MAIN
76 HTG. RETURN FROM RADIATION & HEATER SYSTEM
SET 55°C (PORT "A" OPEN ON TEMP. RISE.
A
AB
64 HTG. RETUR TO N.C.P.C. BUILDING
76 HTG. RETURN FROM SUPPLY AIR UNIT COILS.
64 HTG. SUPPLY FROM N.C P.C. BUILDING 60-75°C

SCHOOL HEATING SYSTEM SCHEMATIC

FIG.6


SCHOOL - OIL FIRED BOILER (ONE SHOWING FOR CLARITY)
DISTRIBUTION CIRCULATING PUMP
WARM AIR SUPPLY
TO
AIR HEATER
FROM
ANOTHER AIR HEATER, BASEBOARD HEATER AND OTHER BLDG SERVICES HEATING DEVICES & THEIR LOCAL TEMP. CONTROL
WARM AIR RETURN
ENERGY METERING
CIRCULATING PUMP
ANNUNCIATOR PANEL INDICATING ABNORMALITIES IN HEATING SYSTEM
B.P.
B.P.
BY-PASS CONTROL
SCHOOL BUILDING
EXHAUST GASSES FLOW CONTROL VALVE REQUIRED TO OPEN DIRECTLY TO ATMOSPHERE WHEN SCHOOL HEAT DEMAND DROPS OR FOR MAINTENANCE & PROTECTION PURPOSES
EXHAUST GASSES TO LIQUID HEAT EXCHANGER
BY-PASSING FLOW ONLY WHEN INCOMING TEMPERATURE TOO LOW AND THEREFORE BOILER REQUIRED TO FIRE UP
N.C.P.C. BUILDING
DIRECTLY TO ATMOSPHERE
B.P.
ENGINE RAD
THERMOSTATICALLY CONTROLED ENGINE COOLING FAN MOSTLY RUNNING ONLY IN SUMMER WHEN SCHOOL HEAT DEMAND MINIMAL.
ACTUATOR
B.P.
RECIRCULATION OF JACKET WATER PREVENTING UNDESIRABLE SUB-COOLING AND THERMAL LOSSES OTHERWISE
B.P.
ENGINE JACKET WATER CIRCULATION LOOP. NOTE: ONE (1) ENGINE ONLY SHOWN FOR CLARITY
LIQUID TO LIQUID HEAT EXCHANGER
INDICATES BY-PASS PIPE C/W VALVES FOR DE-COMMISSION & MAINTENANCE PURPOSES (TYPICAL)
ENGINE JACKET WATER PUMP
ENGINE
GENERATOR
GEN SET

HEAT RECOVERY FUNCTIONAL DIAGRAM

FIG. 7

A.3

TABLES

TABLE 1

LAC LA MARTRE HEAT RECOVERY STUDY

DATE	TIME	OUTSIDE AIR TEMP. (°C)	WATER SUPPLY TEMP. (°C) (RED BOTTON)	WATER RETURN TEMP. (°C) (BLUE BOTTON)	Δ T READING ON TEMP. DIAL	WATER FLOW M^3	ENERGY MWh	OIL DAY TANK GUAGE (LITRES)
JAN 7	14-24	-24	65	49	16	13187.9	157.19	145.00
7	15-31	-24	65	52	13	13196.4	157.325	— " —
8	14-10	-20	67	52.5	14.5	13370.7	159.20	— " —
9	14-55	-29	66	52	14	13561.9	161.43	— " —
10	14-35	-34	61	49	12	13745.9	163.69	— " —
11	14-00	-32	61	48	13	13926.8	165.92	— " —
12	13-50	-30	62	50	12	14110.9	168.19	— " —
13	14-00	-26	65	51	14	14303.1	170.54	— " —
14	11-45	-26	76	72	4	14464.6	172.31	— " —
15	——	-25						
16	15-00	-23	78	74	4	14873.3	174.83	145.00
17	9-15	-20	78	74	4	15016.5	175.91	— " —
18	14-00	-20	58	50	8	15243.6	178.38	— " —
19	15-00	-15	78	66	11	16438.1	180.43	— " —
20	10-00	-22	73	60	12	15585.6	181.97	— " —
21	10-00	-22	76	64	13	15768.5	184.00	— " —
22	——	-26						
23	——	-30						
24	10-40	-33	70	58	12	16341.4	190.98	145.00
25	10-00	-36	68	56	12	16526.1	192.96	— " —
26	9-00	-30	64	52	12	16688.5	194.69	— " —
27	9-00	-25	66	56	10	16880.6	196.85	— " —

TABLE 1.

LAC LA MARTRE HEAT RECOVERY STUDY

DATE	TIME	OUTSIDE AIR TEMP.(°C)	WATER SUPPLY TEMP. (°C) (RED BOTTON)	WATER RETURN TEMP.(°C) (BLUE BOTTON)	Δ T READING ON TEMP. DIAL	WATER FLOW M³	ENERGY MWh	OIL DAY TANK GUAGE (LITRES)
JAN 28	9.00	-25	76	68	9	17074.9	198.84	145.00
29	13.00	-18	70	54	14	17301.6	201.66	"
31	13.00	-32	60	48	12	17679.1	206.06	"
FEB 1	10.00	-37	68	58	10	17845.2	207.98	"
2	9.00	-38	72	60	12	18031.1	210.18	"
3	9.00	-38	60	50	10	18222.3	212.62	"
4	9.00	-37	64	52	12	18416.7	214.74	"
5	13.00	-38	60	50	10	18638.7	217.43	"
6	17.00	-38	60	50	10	18867.1	219.97	"
13	13.00	-23	70	62	8	20181.7	233.92	"
14	8.30	-20	68	58	10	20288.7	235.89	"
15	9.00	-28	70	60	10	20469.8	237.31	"
16	9.00	-30	65	54	11	20660.6	239.42	"
17	9.00	-34	65	52	12	20835.2	241.65	"
18	9.00	-28	72	62	10	21018.8	248.69	"
21	11.00	-15	75	64	11	21570.1	249.90	"
22	9.00	-12	70	58	12	21738.0	251.68	"
24	8.30	-12	60	62	2	22099.3	255.95	"
25	8.30	-6	66	58	8	22278.6	257.97	"
26	9.00	-30	66	70	8	22464.2	260.24	"
28	10.00	-23	76	68	24	22857.6	261.08	"

TABLE 1

LAC LA MARTRE HEAT RECOVERY STUDY

DATE	TIME	OUTSIDE AIR TEMP. (°C)	WATER SUPPLY TEMP. (°C) (RED BOTTON)	WATER RETURN TEMP. (°C) (BLUE BOTTON)	Δ T READING ON TEMP. DIAL	WATER FLOW M³	ENERGY MWh	OIL DAY TANK GUAGE (LITRES)
MAR 1	9.00	-20	62	70	8	23031.8	262.94	145.00
2	9.00	-38	64	58	18	23218.7	26494	"
3	11.00	-20	58	50	10	23424.7	267.36	"
4	9.00	-19	62	60	2	23771.1	270.76	"
9	8.30	-8	60	62	6	24493.5	276.89	"
10	8.30	-8	70	64	18	24666.9	278.51	"
11	8.45	-12	64	62	10	24848.0	280.72	"
14	8.30	-22	60	52	8	25397.0	286.57	"
15	8.30	-20	62	52	10	25585.1	288.53	"
16	8.30	-20	60	48	12	25783.0	290.61	"
17	8.30	-16	58	48	10	25955.1	292.57	"
18	8.30	-10	58	48	10	26136.7	294.54	"
23	11.30	-15	60	42	18	27079.4	304.01	"
24	9.00	-15	58	48	10	27258.2	305.98	"
25	10.00	-16	60	50	10	27432.5	307.80	"
28	11.00	-20	58	60	2	27996.3	309.83	"
29	9.00	-21	58	62	8	28167.6	310.67	"
30	9.00	-15	60	60	0	28345.0	311.41	"

TABLE 1.

LAC LA MARTRE HEAT RECOVERY STUDY

DATE	TIME	OUTSIDE AIR TEMP.(°C)	WATER SUPPLY TEMP. (°C) (RED BOTTON)	WATER RETURN TEMP.(°C) (BLUE BOTTON)	ΔT READING ON TEMP. DIAL	WATER FLOW M³	ENERGY MWh	OIL DAY TANK GUAGE (LITRES)
APR 5	10.00	2	68	62	6	29434.7	315.07	145.00
6	10.00	-2	68	60	8	29617.2	316.49	"
7	9.00	-6	56	50	6	29789.3	317.70	"
8	10.00	-10	62	88				
11	9.30	-8	58	50	8	30546.3	323.78	145.00
15	9.00	-8	62	54	8	31266.7	329.07	"
18	9.00	-4	72	64	8	31814.0	333.17	"
20	11.00	-3	72	64	8	32363.7	337.67	"
26	10.50	-8	72	64	10	82249.6	344.59	"
27	11.10	-8	73	65	10	32437.5	346.18	"
28	9.30	-6	72	64	10	33601.6	347.65	"

TABLE 1

LAC LA MARTRE HEAT RECOVERY STUDY

DATE	TIME	OUTSIDE AIR TEMP (°C)	WATER SUPPLY TEMP. (°C) (RED BOTTON)	WATER RETURN TEMP (°C) (BLUE BOTTON)	Δ T READING ON TEMP. DIAL	WATER FLOW M³	ENERGY MWh	OIL DAY TANK GUAGE (LITRES)
MAY 2	9.00		58	52	6	34513.5	354.93	145.00
3	9.00		68	64	4	34696.4	356.52	"
4	9.00		66	58	10	34885.7	358.12	"
5	9.00		70	68	4	35054.1	359.60	"
9	9.00	-1	56	50	6	35574.0	363.45	"
10	11.00	-1	64	60	4	35759.9	364.57	"
11	11.00	0	72	72	0	35938.9	364.88	"
12	10.00	2	54	46	8	36096.8	366.08	"
13	9.00	1	56	48	8	36286.2	367.95	"
16	9.00	-4	54	50	4	36818.3	370.97	"
17	9.00	-3	60	50	10	36985.8	374.72	"
18	9.00	-1	66	60	6	37161.1	376.25	"
19	9.00	0	60	54	6	37335.2	377.99	"
20	9.00		66	58	8	37505.2	379.61	"
24	9.00		68	60	8	38205.2	385.82	"
25	9.00		66	56	10	38380.5	387.52	"
26	9.00		64	54	10	38546.1	389.14	"
27	10.30		68	60	8	38727.1	390.95	"
30	9.00		66	60	6	39220.9	395.40	"
31	9.00		68	62	6	39389.3	396.80.	"

TABLE 1

LAC LA MARTRE HEAT RECOVERY STUDY

DATE	TIME	OUTSIDE AIR TEMP.(°C)	WATER SUPPLY TEMP. (°C) (RED BOTTON)	WATER RETURN TEMP.(°C) (BLUE BOTTON)	Δ T READING ON TEMP. DIAL	WATER FLOW M³	ENERGY MWh	OIL DAY TANK GUAGE (LITRES)
JUNE 1	9·00	4	64	56	8	39556·9	398·28	145.00
2	8·30	4	64	54	10	39723·2	399·85	〃
3	9·30	6	72	64	8	39903·4	401·42	〃
6	9·30	8	68	60	8	40402·9	405·52	〃
7	9·15	6	68	62	6	40569·5	407·01	〃
8	9·25	5	68	62	6	40749·6	408·50	〃
9	8·35	8	72	64	8	40912·8	409·95	〃
10	9·20	10	74	64	10	41085·9	411·54	〃
13	10·00	14	76	66	10	41589·1	415·25	〃
15	9·36	17	74	66	8	41921·7	417.90	〃
16	9·35	18	58	52	6	42094·1	419.18	〃
19	4·30	14	68	60	8	42643·7	422·61	〃
20	10·40	14	62	56	8	42771·9	422·82	〃

TABLE 2 - INTERIM PREDICTIONS, FEBRUARY 1983

1983	Predicted Generator Electrical Output KWH	Predicted Generator Heat Output (Recoverable)	Predicted School Heat Requirements KWH	Predicted Degree Days
Jan.	53,325	70,389	60,634	1,360
Feb.	55,000	72,930	51,288	1,200
Mar.	50,500	66,660	44,517	1,050
Apr.	45,500	60,060	29,254	690
May	34,500	45,747	13,567	320
Jun.	30,500	40,443	5,088	120
Jul.	26,000	34,476	2,544	60
Aug.	20,000	26,520	5,045	119
Sep.	45,000	59,670	13,143	310
Oct.	51,000	67,626	27,558	650
Nov.	53,000	70,278	41,549	980
Dec.	55,500	73,593	54,946	1,296

TABLE 3 - INTERIM HEAT RECOVERY FINANCIAL EVALUATION, FEBRUARY 1983

Present value of capital investment: $185,000
Total Fuel Saving: : $ 45,314 litres per year.

Payment Number	Total Fuel Saving (PV)	Principal Outstanding(PV)
1	$ 30,224	$154,776 -
2	$ 59,015	$125,985 -
3	$ 86,666	$ 98,334 -
4	$113,343	$ 71,657 -
5	$139,121	$ 45,879 -
6	$164,823	$ 20,177 -
7	$189,895	$ 4,895
8	$213,888	$ 28,888

Discount Rate: 10%

The break-even occurs in the seventh year.

There is an additional cost, for the heat recovery system, of the electricity for the recirculation pump. This amounts to $2,079 per year.

Due to the present situation, when the discount rate and inflation rate are so unstable, the above table can only be an approximation.

TABLE 4 - FINAL DATA, AUGUST 1983

1983	Generator Electrical Output KWH	Generator Heat Output (Recoverable)	School Heat Requirements KWH	Degree Days
Jan.	53,325	70,389	60,634	1,370
Feb.	51,200	67,584	54,960	1,247
Mar.	30,875	40,755	50,090	1,053
Apr.	39,375	51,975	38,820	693
May	36,450	48,114	44,810	315
Jun.	34,500	45,540	34,780	156
Jul.	28,400	37,488	13,377	60
Aug.	30,200	39,864	26,531	119
Sep.	36,100	47,350	32,870	310
Oct.	36,932	48,750	36,410	650
Nov.	40,237	53,113	46,620	980
Dec.	45,265	59,750	57,120	1,296

TABLE 5 - HEAT RECOVERY FINANCIAL EVALUATION, AUGUST 1983

LAC LAMARTRE SCHOOL RECOVERY OPTION - EX + JW

NCPC/GNWT EQUIVALENT FUEL COST SHARING RATIO % 100 : 0.0
PRESENT VALUE - CAPITAL INVESTMENT = $ 249000.00

FINANCIAL EVALUATION

PAYMENT NO.	TOTAL FUEL SAVING PV	PRINCIPAL OUTSTANDING PV
1	$ 26488.56	$ 222511.44-
2	$ 53220.13	$ 195779.87-
3	$ 80196.94	$ 168803.06-
4	$ 107421.25	$ 141578.75-
5	$ 134895.33	$ 114104.67-
6	$ 162621.46	$ 86378.54-
7	$ 190601.95	$ 58398.05-
8	$ 218839.15	$ 30160.85-
9	$ 247335.41	$ 1664.59-
10	$ 276093.10	$ 27093.10
11	$ 305114.62	$ 56114.62
12	$ 334402.39	$ 85402.39
13	$ 363958.86	$ 114958.86
14	$ 393786.49	$ 144786.49
15	$ 423887.77	$ 174887.77
16	$ 454265.21	$ 205265.21
17	$ 484921.33	$ 235921.33
18	$ 515858.71	$ 266858.71
19	$ 547079.92	$ 298079.92
20	$ 578587.56	$ 329587.56

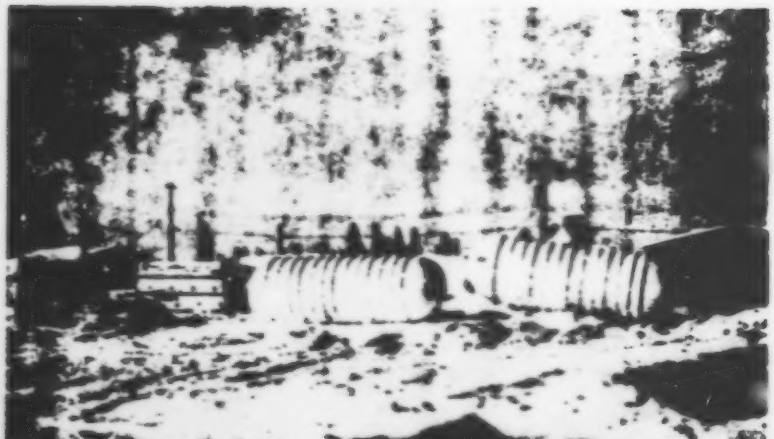
TOTAL FUEL SAVING = 49780. LITRES PER YEAR
DISCOUNT RATE - 9 %; FUEL INFLATION RATE - 10 %

BREAK - EVEN AT YEAR 9

A.4

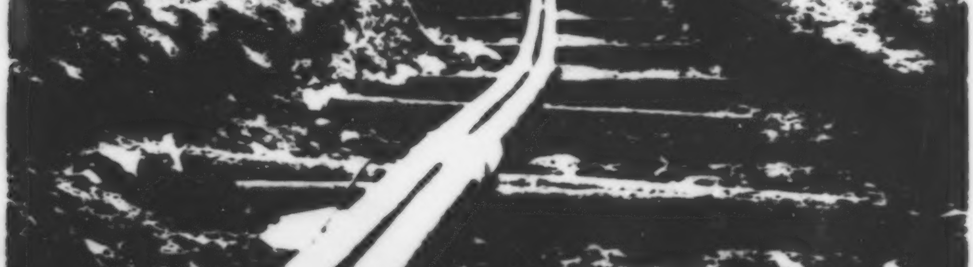
PHOTOGRAPHS

SCHOOL DURING CONSTRUCTION

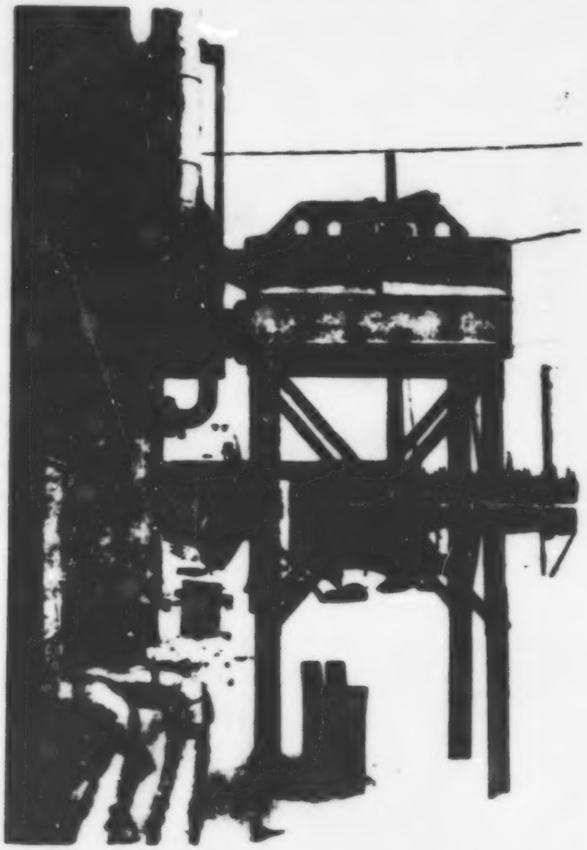


STORAGE CONSIDERATIONS IN THE SNOW DURING EARLY CONSTRUCTION

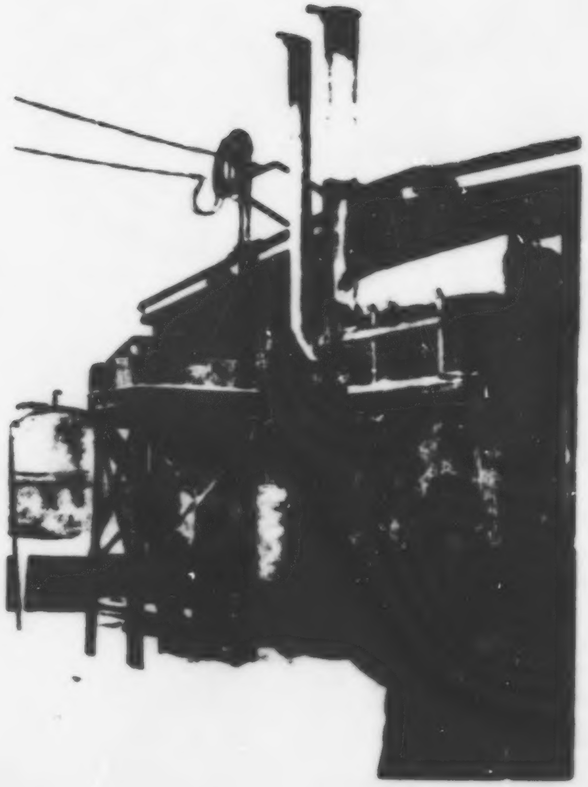
METAL CLAD INSULATED HEATING PIPES PASSING OUT OF NCPC BUILDING



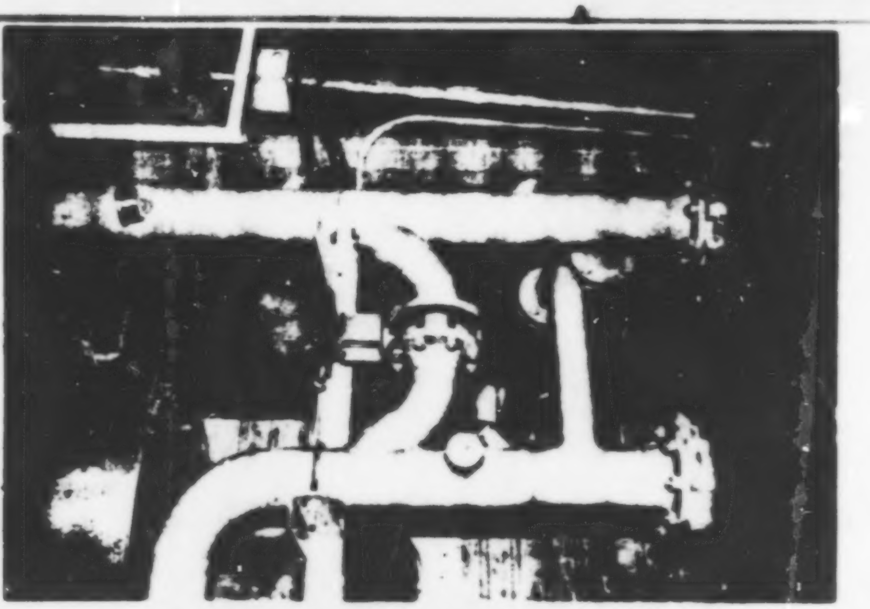
BURIED HEATING PIPES FROM NCPC BUILDING (BACKGROUND) TO SCHOOL



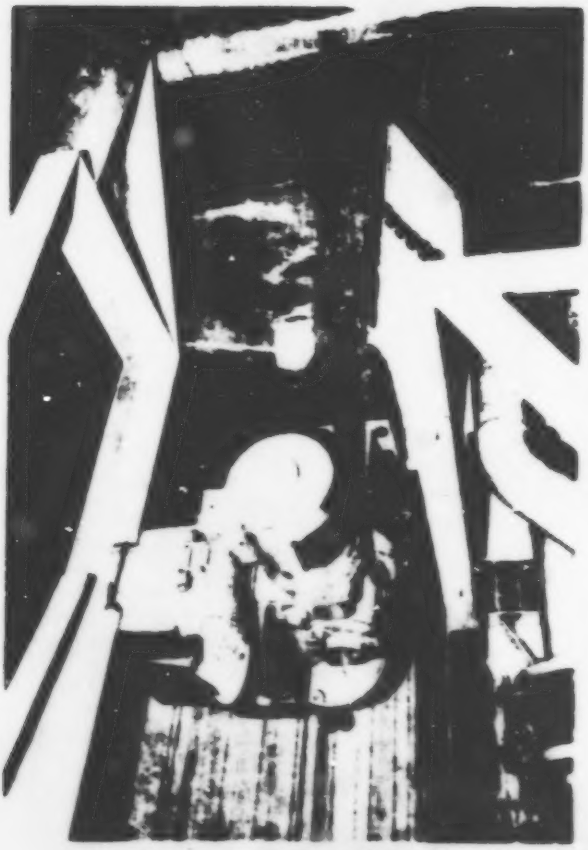
EXISTING
NCPC ENGINE
RADIATOR



ENGINE RADIATOR
& TWO FLUES FROM
NCPC BUILDING

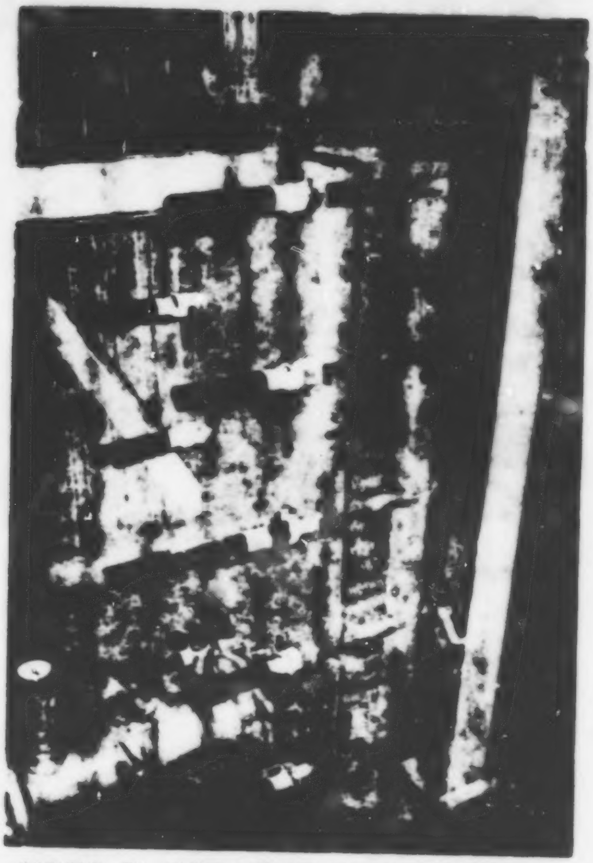


RADIATOR BYPASS

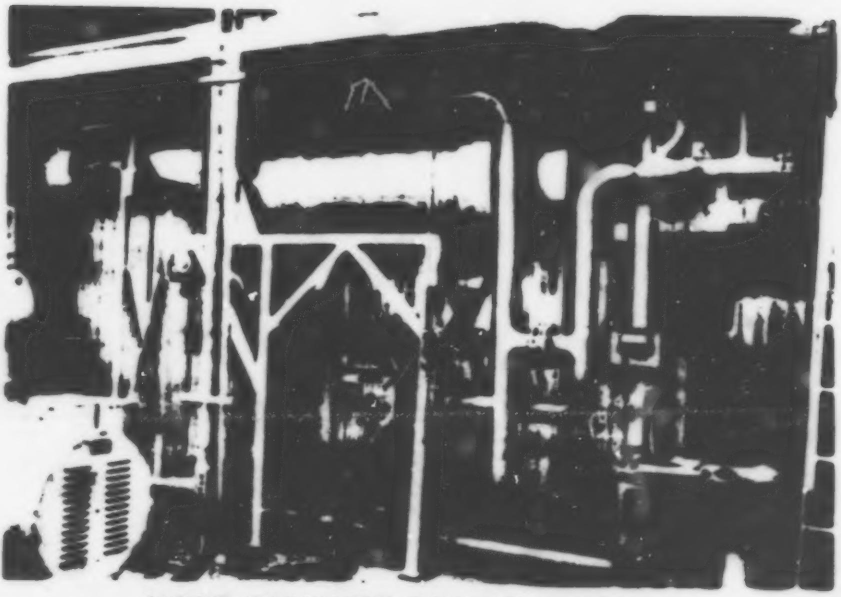


EXHAUST GASES FLOW CONTROL VALVE DIRECTING HOT GAS EITHER THROUGH EXHAUST BOILER OR DIRECTLY TO OUTSIDE

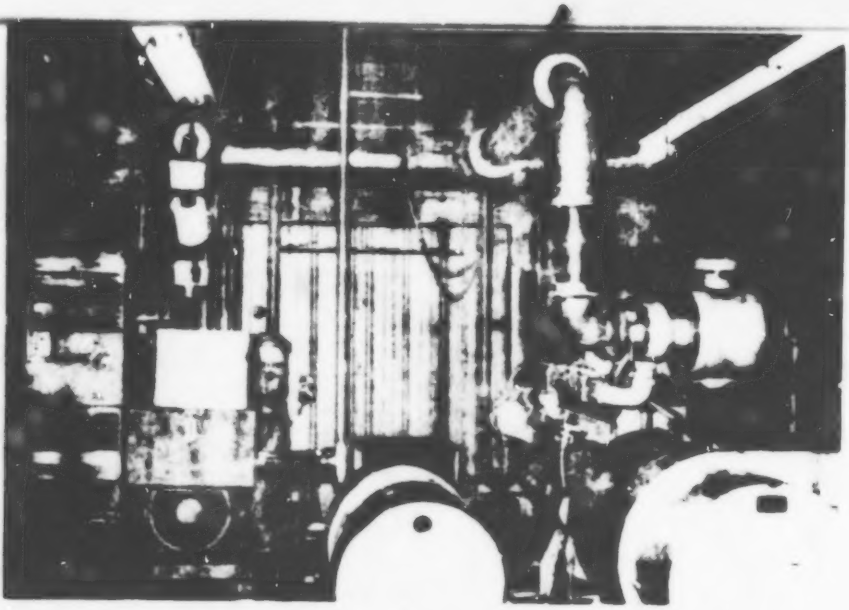
P.4



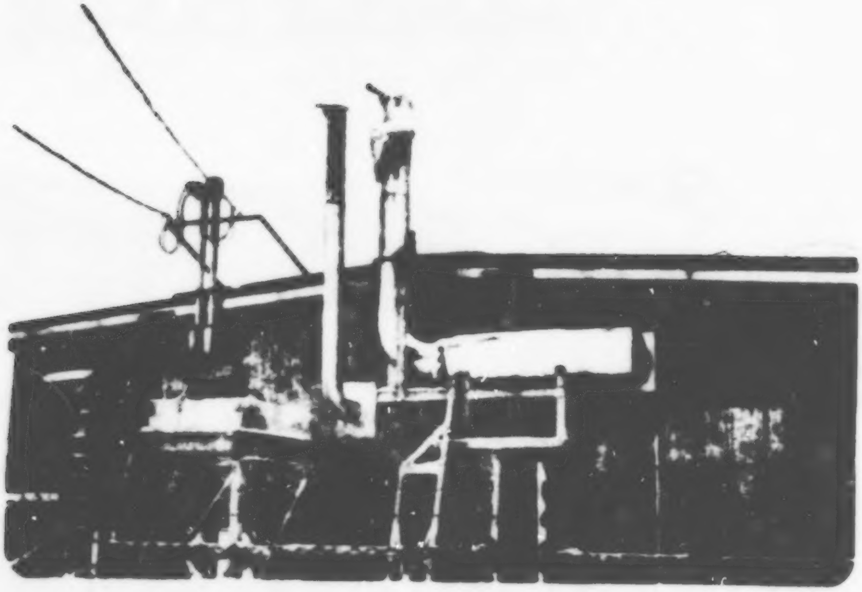
NCPC PLATE HEAT EXCHANGER



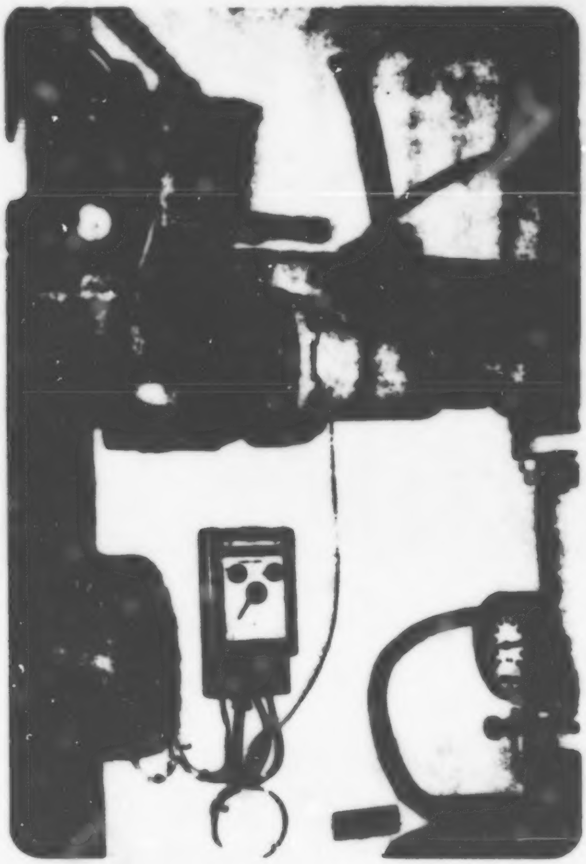
NCPC EXHAUST BOILER ABOVE PLATE HEAT EXCHANGER



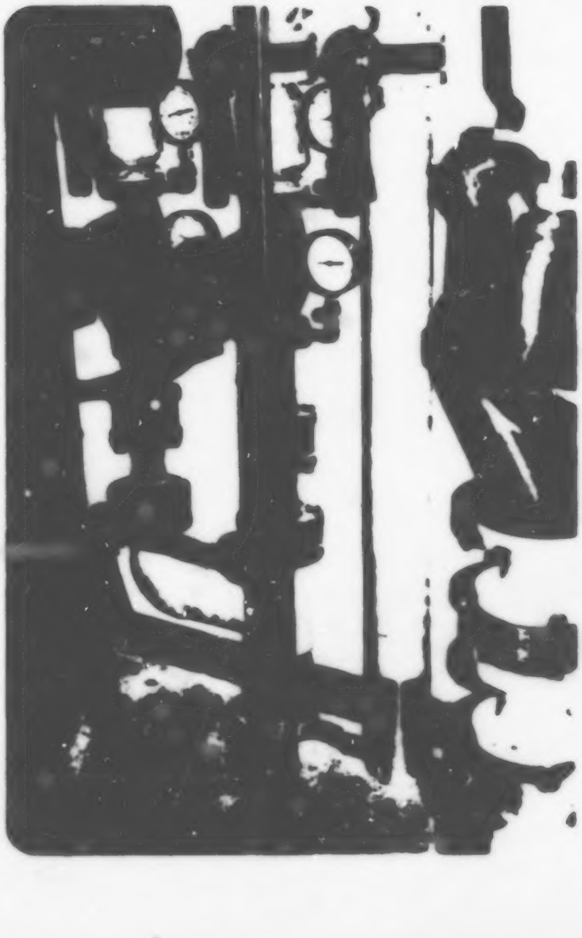
ELEVATION OF DD4-71 AND D-342 GENERATORS



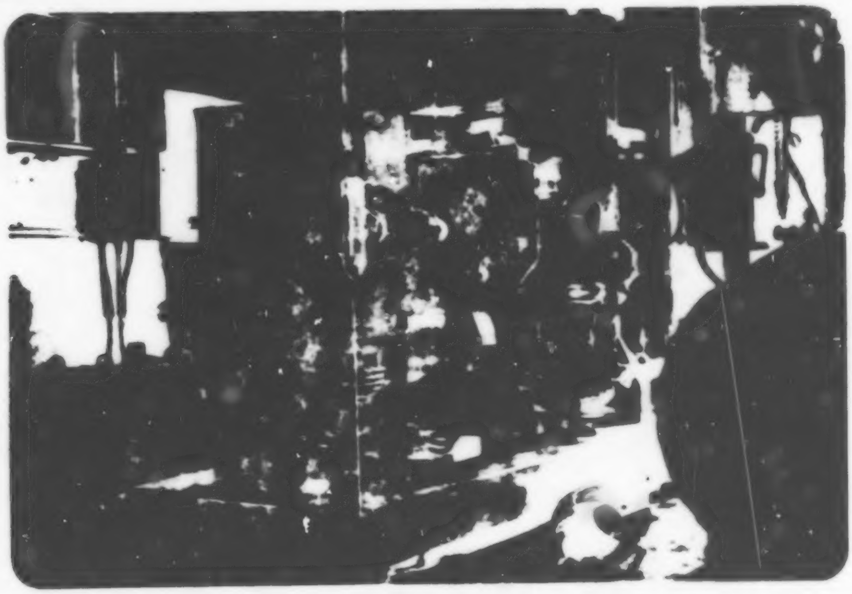
FLUES FROM N.C.P.C. BUILDING, RIGHT HAND "BYPASS" FLUE ICING UP DUE TO LACK OF USE



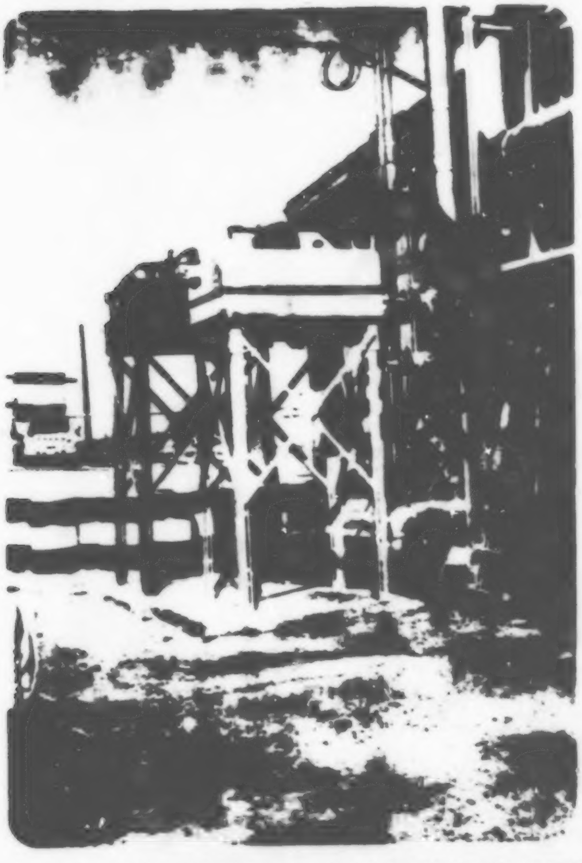
BTU METER WITHIN SCHOOL BOILER ROOM.



NCPC HOT WATER PIPES ENTER SCHOOL BOILER ROOM FROM CRAWLSPACE BELOW.



NEW GENERATOR (MAY/83)



NEW RADIATOR (ON FAR SIDE)

A.5

ORIGINAL PROPOSAL

Design Proposal for Lac La Martre School
November 1981

PROPOSAL

ENERGY CONSERVATION PROJECT
LAC LAMARTRE ELEMENTARY SCHOOL
GNWT PROJECT : 80-098

NOVEMBER 1981

PREPARED FOR:

GOVERNMENT OF THE NORTHWEST TERRITORIES

PREPARED BY:

FERGUSON NAYLOR, SIMEK, CLARK LIMITED
CONSULTING ENGINEERS & ARCHITECTS

4912 53rd STREET P.O. BOX 1777, YELLOWKNIFE, N.W.T. CANADA X1A 2P4

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1. RESTRICTIONS OR PROPRIETARY NOTICE

2. PROJECT SUMMARY

3. PROJECT JUSTIFICATION

4. TECHNICAL DESCRIPTION

    4.1 Statement of Work to be Financed
    4.2 Outline of Work Program
    4.3 Location

5. PROJECT MANAGEMENT

6. INFORMATION TRANSFER

7. ENERGY SAVINGS ANALYSIS

    7.1 Cost to Heat Building Using Only Boilers Without Combined Waste Heat Recovery
    7.2 Use of Heating Coils in Crawl Space Vs. Radiation
    7.3 Oversizing Pipes
    7.4 Night Set Back
    7.5 Shut Down of Circulation Pumps on Air Handling Equipment When Not In Use
    7.6 Shut Down of Radiation Circulation Pumps When all Zones are Satisfied

8. ANALYSIS

    8.1 Summary of Energy Conservation Savings & Costs Taken Cumulatively
    8.2 Analysis of Conservation Funding Sought

9. SUMMARY

10. APPENDIX

    Computer Analysis of Waste Heat Source and Sink (FNSC WHeat Program).

RESTRICTIONS OR PROPRIETARY NOTICE 1

1. Restrictions of Proprietary Notice

There is no restricted or proprietary information contained in this submission.

PROJECT SUMMARY 2

2: Project Summary

The new 1700 m^2 school designated for Lac La Martre will be constructed in one of the highest energy cost areas in the Northwest Territories when both fuel and electricity are considered. As a result of these costs, the Territorial Government will take extraordinary measures to provide the most favourable life cycle cost profile.

This school will be the first major project in the Territories to be designed from first principles to accommodate full jacket water and exhaust heat recovery from the town's main diesel generating plant. This feature is important in that it allows the use of higher grade heat with corresponding lower pumping requirements than a simple jacket water installation.

In addition, other features incorporated in the design will complement each other to minimize the building's requirements for external energy to the greatest practical extent.

PROJECT JUSTIFICATION 3

3. Project Justification

This project is justified on the basis of the high cost of fossil fuels and electricity at Lac La Martre in conjunction with the future trends for energy. At present, electricity is 52.2¢ per kWh and fuel is $1.98 per gallon.

This project represents a new development in that it is capable of using the exhaust gas heat from the generating station as well as waste jacket water heat. The project represents a milestone in the Territorial Program to utilize diesel waste heat in that the total system is designed to complement remaining extra-ordinary measures taken to minimize operating costs for the school.

It is therefore necessary to look at the combined waste heat recovery in context with the remaining extraordinary energy efficient measures outlined in this proposal.

These concepts are applicable to future projects throughout the Territories, and will establish a working relationship for exhaust gas recovery with the Northern Canada Power Commission.

TECHNICAL DESCRIPTION 4

4. Technical Description (refer to plans & specifications)

4.1 Statement of work to be financed

.1 Install exhaust and jacket water waste heat recovery system from Northern Canada Power Commission plant with lines to school, as shown on plans.

.2 Increase pipe sizes throughout the building in order to minimize pipe friction losses so that smaller pumps can be used. This is especially important for circulating pumps which must run for long periods of time.

.3 Pump(s) operating the air handling heating coils will shut down automatically when the units are not operating. In order to prevent freezing air in the building on ventilation start up, the pump will start 3 minutes before the air handling unit. The units are, of course, on time clocks with manual overrides.

4.1 Statement of work to be financed (continued)

.4 Building circulation pumps for radiation will shut down automatically when all zones are satisfied.

.5 All room radiation thermostats have night set back features which can be adjusted on a room-by-room basis.

.6 Crawl space heating is to be coil/air system designed to meet the heating and dehumidification requirements on a 12 month basis considering optimum life cycle costing.

4.2 Outline of work program

The attached plans and specifications shown the interrelationships between the proposed energy features and the remainder of the project.

4.3 Location

This work will be performed during 1982 in Lac La Martre. It is a new project, with the exception of the tie-in to the diesel generating station.

PROJECT MANAGEMENT 5

5. Project Management

This project is tendered on behalf of the Government of the Northwest Territories, using Ferguson, Naylor, Simek, Clark Limited as consultants. Project control will be handled by the Government of the Northwest Territories and the consultants.

Project reporting will be carried out as work progresses, up to the Final Inspection. Operational data will be kept for one year, then evaluated by Ferguson, Naylor, Simek, Clark Limited in accordance with the projected / actual savings.

INFORMATION TRANSFER 6

6. Information Transfer

Ferguson, Naylor, Simek, Clark Limited will compile an information package on the completed system, with a follow up report on performance after one year of operation. Copies (up to 20) of the information package will be made available to any interested parties. Cost of producing this finished report is estimated at $10,000.00.

ENERGY SAVINGS ANALYSIS 7

7. Savings Analysis

We are using the current prices for electricity of $.522 per KWh and $1.98 per gallon of fuel oil. Boiler efficiencies are taken as 80% using No. 2 fuel oil. Initially, these savings are considered independently of each other, and are then adjusted as described at the end of this section.

7.1 Cost to Heat Building Using Only Boilers Without Combined Waste Heat Recovery

Fuel oil required: 12,600 gallons/year

125,000 BTU/gallon @ 80% efficiency

Burner operating time:	
3,322 hours at 1/2 HP (.25 kW) = 1,661 kWh	1,661 kWh
Oil transfer pumps:	
200 hours at 1/2 HP (.5 kW) = 100 kWh	100 kWh
Total kWh	1,761 kWh

Therefore, cost for heat:	
Fuel: 12,600 gallons x $1.98	$ 24,948.00
Electricity: 1,761 kWh x $.5222	919.00
Total heating costs (incl. electrical power)	$25,867.00

Energy efficient alternative: using UCPC waste heat:

Cost of recirc pump:	
3/4 HP for 270 days = 4,860 kWh at $.522	$ 2,536.00
Supplemental boiler heat requirements (80,000 kWh)	
Fuel: 2,182 gallons x $1.98	4,321.00
Boiler electrical and transfer pumps:	
300 kWh at $.522	256.00
Total cost using waste heat	$ 7,013.00
Therefore: total direct costs using waste heat (including electrical costs)	$ 7,013.00
Therefore: gross savings using NCPC waste heat is given by $25,867 - $7,013.00	$ 18,854.00
If NCPC charges for 50% of the equivalent costs, the charge to the GNWT is: 12,600 gallons less 2,182 = 10,418 gallons at $.99	$ 10,314.00
Therefore: the net savings with this approach would be:	
$18,854 - $10,314 (incl electrical costs)	$ 8,540.00/annum

Should NCPC waive the 50% charge on waste heat, then the net savings jump from $8,500.00 per annum to $18,800.00 per annum, which is extremely attractive.

7.2 Use of heating coils in crawl space vs radiation

Coils can delivery more BTU's per GPM at a given supply temperature, and thus require lower circulating pump power to deliver a given heat output than finned radiation. Offsetting the lower pump requirements is the need for fan power to extract the heat from the coil.

Basically, the crawl space finned radiation would require a circulation pump of 1 HP larger than that for the fan/coil. The analysis compares as follows:

Cost for extra circulation pump horsepower:	
300 days x 24 hrs x 1 kW x $.522	$ 3,758.00
Versus	
Cost for running fan motors:	
1.3 kW x 300 hrs = 400 kWh at $.522	208.00
Net annual benefit using unit heaters versus radiation:	$ 3,550.00

7.3 Oversizing pipes

This item reduces system friction losses throughout the system by a total of 4 HP over the standard ASHRAE approach; essentially on the circulation pumps that operate throughout the heating season.

Considering 300 days operation for the system, simple pipe sizing savings are:

$3,758.00 x 4 $ 15,032.00

7.4 Night set back

This will result in an annual reduction of abour 7% on the annual heat requirements

7.5 Shut down of circulation pumps on air handling equipment when not in use

"1" kW x 100 hrs/wk x 40 wks x $.522 $ 2,100.00

7.6 Shut down of radiation circulation pumps when all zones are satisfied (excluding system shut down for 2 months in summer)

"2" kW x 2,400 hrs/yr at $.522 $ 2,500.00

However, the 7% reduction in the cold winter months will show up mainly as a reduction in supplemental fuel oil requirements when waste heat is insufficient to carry the building. During the remainder of the heating season, the 7% reduction is saved simply in reduced use of waste heat. The issue then becomes one of saving electrical pumping power on the radiation, which will be addressed later.

Considering that the supplemental fuel is required during the coldest months, it is reasonable to assume that the night set back will also result in a savings of 7% of the supplemental fuel burned. (As can be seen, if 100% of the heating requirements could be made up by waste heat, the net community savings would be nil with night set back, excluding reduced pump operation.) Again, the night set back savings will be considered in context with Item 7.1.

It should be understood that the savings of $18,540.00 per annum already considers that the ventilation fans are on the normal time clock operation.

Combined Savings Analysis

The reality of energy conservation measures are that the predicted savings result ONLY when the items are considered in isolation. Any combination of the above will produce non-linear relationships in savings not predicatable by simply adding the savings. In most cases, the combined savings of any number of items will generally be less than their algebraic sum. (You may quote this generalization as Ferguson's Rule of Reality for Cumulative Conservation). There are in excess of 40 permutations and combinations which can be considered, each which must be addressed as a specific solution.

Our analysis was such that the six items mentioned above give the best combined savings for the investment, considering life cycle costs. Briefly, the considerations for interaction are described below:

Item 7.1 must be reviewed considering interaction with Item 7.4 (Night Set Back), which reduces the overall building heating requirements by 7%.

Item 7.2 must be considered in conjunction with Item 7.3. When pump reductions are included, not only is the GPM affected per Item 7.2, but the friction losses are less. This also has the effect of reducing pump horsepower requirements, but not in the same proportion as flow reductions. In addition, Item 7.6 will affect the overall savings for Item 7.2.

Had oversizing pipes been considered above, the system horsepower savings would have been a total of 4 HP stated. However, due to the reduced flows per Item 7.2 and shut down of pumps per Item 7.5 and 7.6 as well as night set back of Item 7.4, the oversizing of pipes savings must be adjusted in that context.

Item 7.5 must be considered in light of the minimum sized pumps which result from Item 7.3. (It should be noted that the calculation in Item 7.5 is so stated.)

Item 7.6 must be considered in light of the minimum sized pumps which result from Items 7.2 and 7.3.

ANALYSIS 8

8.1 Summary of energy conservation savings and costs taken cumulatively

	Net Annual Savings	Energy Cons. Cost Premium
Item 7.1 waste heat recovery	$18,000	$60,000
Item 7.2 coils in crawl space	2,200	3,000
Item 7.3 oversizing pipes	10,000	30,000
Item 7.4 night set back (fuel) - "2" kW x 350 hr (electrical)	750	2,500
Item 7.5 shut down of circ pumps on A/H units	2,100	6,000
Item 7.6 shut down of circ pumps on rad units	2,500	8,000
Totals	$35,550	$109,500

8.2 Analysis of conservation funding sought

Proposed Project Funding Arrangements:

Extra-ordinary energy conservation measures costs	$109,500.00
Information transfer	10,000.00
	$119,500.00
Proposed GNWT contribution:	$ 30,000.00
Conservation funding sought:	$ 89,500.00

SUMMARY 9

9. Summary

The measures discussed in this report are very attractive from a life cycle costing point of view. However, it must be recognized that such measures generally require a higher level of skill to maintain than a simple on-off system.

Considering the size of such buildings and the demands for energy efficient operation, there is no practical way to design the systems around unskilled maintainers.

APPENDIX

Computer Analysis of Waste Heat Source and Sink (FNSC WHeat Program)

10

DEPARTMENT OF PUBLIC WORKS

WASTE HEAT RECOVERY - SOURCE AND MARKET ANALYSIS

LAC LAMARTRE SCHOOL

GENERATOR CAPACITY = 150 KW SUPERCHARGED

MO	GENERATOR OUTPUT (KWH)	HEAT PRODUCED (KWH) JACKET	EXHAUST	COMBINED
1	56000.0	46060.5	53065.4	99125.9
2	47000.0	39158.5	45113.8	84272.3
3	45000.0	37600.4	43318.7	80919.1
4	42000.0	35246.3	40606.6	75852.8
5	30000.0	23984.1	27631.7	51615.8
6	23000.0	19848.1	22866.6	42714.7
7	20000.0	17336.7	19973.3	37310.0
8	15000.0	13100.6	15092.9	28193.5
9	45000.0	37600.4	43318.7	80919.1
10	48000.0	39934.2	46007.4	85941.6
11	51000.0	42248.0	48673.1	90921.1
12	56000.0	46060.5	53065.4	99125.9

MAX. MONTHLY HEAT PRODUCED (KWH) = 99126

MO	HEAT USED IN-PLANT (KWH) JACKET	EXHAUST	RECOVERABLE HEAT (KWH) JACKET	EXHAUST	COMBINED
1	8200.0	0.0	35557.5	29186.0	64743.4
2	7200.0	0.0	30000.6	24812.6	54813.2
3	8100.0	0.0	27620.4	23825.3	51445.7
4	7100.0	0.0	26384.0	22333.6	48717.6
5	3100.0	0.0	19685.0	15197.4	34882.4
6	0.0	0.0	18855.7	12576.6	31432.3
7	0.0	0.0	16469.9	10985.3	27455.2
8	0.0	0.0	12445.6	8301.1	20746.7
9	3000.0	0.0	32720.4	23825.3	56545.7
10	6000.0	0.0	31937.5	25304.1	57241.6
11	7000.0	0.0	33135.6	26770.2	59905.8
12	7800.0	0.0	35957.5	29186.0	65143.4

MAX. MONTHLY HEAT AVAILABLE (KWH)= 65143.

MARKET ANALYSIS

SPECIFIED (OTHER USERS) - LAC LAMARTRE SCHOOL PRELIMINARY DESIGN

MO	DEGREE-DAYS	MONTHLY HEAT MARKET NON-INDUST	INDUST	OTHERS	COMBINED
1	1360.0	0.0	0.0	93304.0	93304.0
2	1200.0	0.0	0.0	84091.0	84091.0
3	1080.0	0.0	0.0	73880.0	73880.0
4	690.0	0.0	0.0	48332.0	48332.0
5	320.0	0.0	0.0	22424.0	22424.0
6	120.0	0.0	0.0	8408.0	8408.0
7	60.0	0.0	0.0	4204.0	4204.0
8	119.0	0.0	0.0	8339.0	8339.0
9	310.0	0.0	0.0	21724.0	21724.0
10	650.0	0.0	0.0	45549.0	45549.0
11	980.0	0.0	0.0	68674.0	68674.0
12	1296.0	0.0	0.0	90819.0	90819.0

MAX. TOTAL MARKET (KWH) = 93304.

WATER DISTRIBUTION SYSTEM OPTION	PIPE SIZE (MM)	FLOW RATE (L/S)	AVERAGE MONTHLY HEAT LOSS MAINS (KWH)	BRANCH (KWH)	SYSTEM (KWH)
JW ONLY	32.	1.07	1605.	688.	2293.
EX ONLY	25.	0.44	1726.	801.	2526.
EX + JW	32.	0.97	1959.	801.	2760.

LENGTH OF MAINS (METRES) = 75.
NO. OF SERVICE CONNECTIONS = 1.

MO	POTENTIAL MARKET UTILIZATION SUMMARY (KWH) PRODUCED	RECOVERABLE	JW ONLY	EX ONLY	EX + JW
1	99125.9	64743.4	33264.3	26659.6	61983.8
2	84272.3	54813.2	27707.6	22286.2	52053.6
3	80919.1	51445.7	25327.4	21298.9	48686.1
4	75852.8	48717.6	24091.0	19807.2	43958.0
5	51615.8	34882.4	17392.0	12471.0	22424.0
6	42714.7	31432.3	8408.0	8408.0	8408.0
7	37310.0	27455.2	4204.0	4204.0	4204.0
8	28193.5	20746.7	8339.0	5774.7	8339.0
9	80919.1	56545.7	21724.0	21298.9	21724.0
10	85941.6	57241.6	29644.5	22777.7	45549.0
11	90921.1	59905.8	30842.6	24243.8	57166.2
12	99125.9	65143.4	33664.5	26659.6	62383.8

GOVERNMENT OF THE NORTHWEST TERRITORIES
DEPARTMENT OF PUBLIC WORKS

WASTE HEAT RECOVERY - COST AVOIDANCE BENEFITS

LAC LAMARTRE SHOOL PRELIMINARY DESIGN RECOVERY OPTION - JW ONLY

NCPC/GNWT EQUIVALENT FUEL COST SHARING RATIO 50.0 : 50.0
PRESENT VALUE - CAPITAL INVESTMENT = $ 39000.00

FINANCIAL EVALUATION

PAYMENT NO.		TOTAL FUEL SAVING PV		PRINCIPAL OUTSTANDING PV
1	$	5815.58	$	33184.42-
2	$	11895.51	$	27104.49-
3	$	18251.80	$	20748.20-
4	$	24897.01	$	14102.99-
5	$	31844.27	$	7155.73-
6	$	39107.32	$	107.32
7	$	46700.51	$	7700.51
8	$	54638.84	$	15638.84
9	$	62938.01	$	23938.01
10	$	71614.41	$	32614.41
11	$	80685.19	$	41685.19
12	$	90168.28	$	51168.28
13	$	100082.42	$	61082.42
14	$	110447.21	$	71447.21
15	$	121283.12	$	82283.12
16	$	132611.57	$	93611.57
17	$	144454.95	$	105454.95
18	$	156836.66	$	117836.66
19	$	169781.19	$	130781.19
20	$	183314.10	$	144314.10

TOTAL FUEL SAVING = 29078. LITRES PER YEAR
DISCOUNT RATE - 10 %; FUEL INFLATION RATE - 15 %

BREAK - EVEN AT YEAR 5

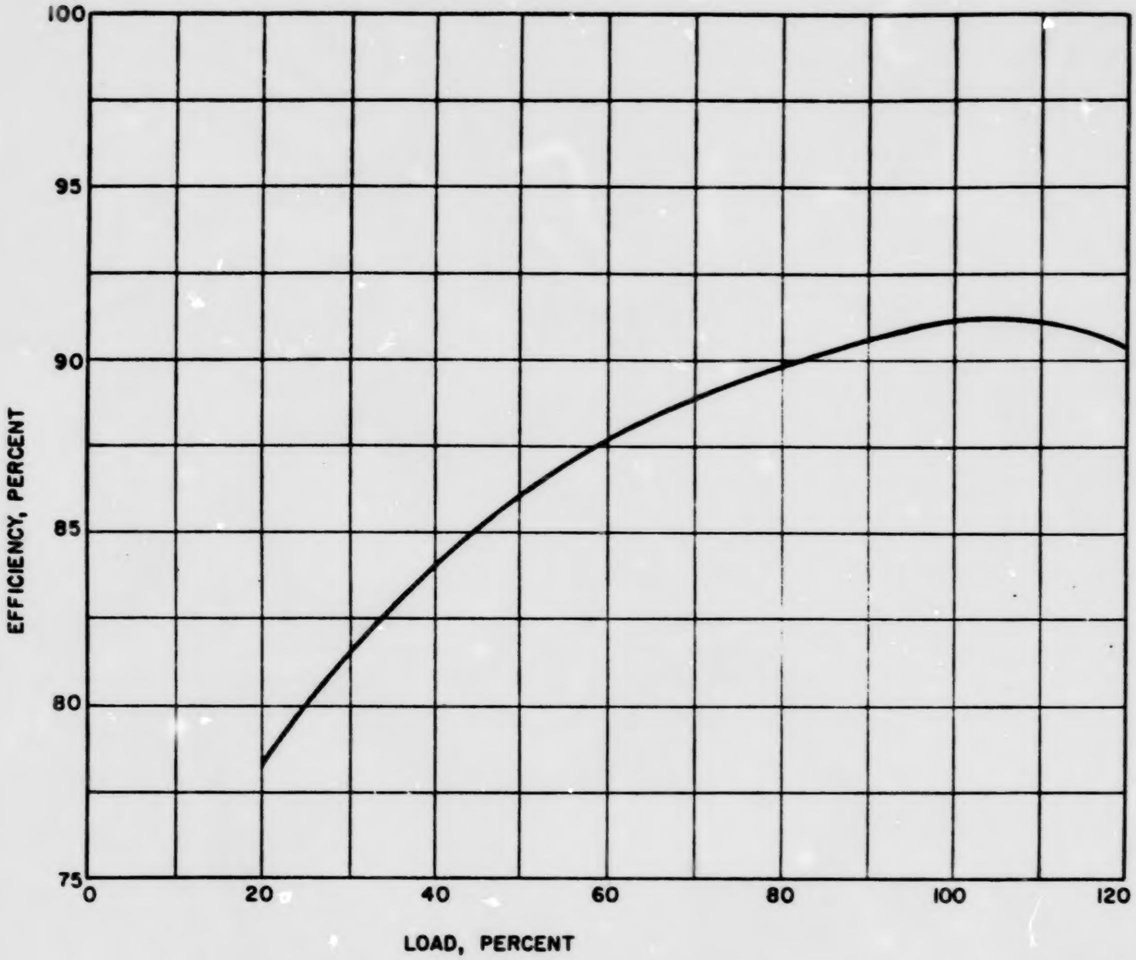
```
LAC LAMARTRE SHOOL PRELIMINARY DESIGN RECOVERY OPTION -  EX ONLY

 NCPC/GNWT EQUIVALENT FUEL COST SHARING RATIO 50.0 : 50.0
PRESENT VALUE - CAPITAL INVESTMENT = $    38000.00

       F I N A N C I A L     E V A L U A T I O N
                                TOTAL             PRINCIPAL
        PAYMENT              FUEL SAVING         OUTSTANDING
          NO.                    PV                  PV

           1      $       4749.21      $       33250.79-
           2      $       9714.29      $       28285.71-
           3      $      14905.06      $       23094.94-
           4      $      20331.77      $       17668.23-
           5      $      26005.15      $       11994.85-
           6      $      31936.41      $        6063.59-
           7      $      38137.27      $         137.27
           8      $      44620.00      $        6620.00
           9      $      51397.39      $       13397.39
          10      $      58482.84      $       20482.84
          11      $      65890.36      $       27890.36
          12      $      73634.58      $       35634.58
          13      $      81730.82      $       43730.82
          14      $      90195.07      $       52195.07
          15      $      99044.05      $       61044.05
          16      $     108295.26      $       70295.26
          17      $     117966.98      $       79966.98
          18      $     128078.33      $       90078.33
          19      $     138649.28      $      100649.28
          20      $     149700.73      $      111700.73

 TOTAL FUEL SAVING =         23746. LITRES PER YEAR
DISCOUNT RATE -  10 %; FUEL  INFLATION RATE -  15 %

 BREAK - EVEN AT YEAR  6
```

```
LAC LAMARTRE   [illegible] PRELIMINARY DESIGN RECOVERY OPTION -  EX + JW

 NCPC/GNWT EQUIVALENT FUEL COST SHARING RATIO 50.0 : 50.0
PRESENT VALUE - CAPITAL INVESTMENT = $    59000.00

       F I N A N C I A L     E V A L U A T I O N
                             TOTAL                PRINCIPAL
      PAYMENT             FUEL SAVING            OUTSTANDING
        NO.                   PV                     PV

         1       $        9645.25       $        49354.75-
         2       $       19728.93       $        39271.07-
         3       $       30270.95       $        28729.05-
         4       $       41292.15       $        17707.85-
         5       $       52814.32       $         6185.68-
         6       $       64860.23       $         5860.23
         7       $       77453.67       $        18453.67
         8       $       90619.54       $        31619.54
         9       $      104383.87       $        45383.87
        10       $      118773.84       $        59773.84
        11       $      133817.91       $        74817.91
        12       $      149545.79       $        90545.79
        13       $      165988.58       $       106988.58
        14       $      183178.77       $       124178.77
        15       $      201150.33       $       142150.33
        16       $      219938.78       $       160938.78
        17       $      239581.25       $       180581.25
        18       $      260116.56       $       201116.56
        19       $      281585.29       $       222585.29
        20       $      304029.87       $       245029.87

  TOTAL FUEL SAVING =          48226. LITRES PER YEAR
DISCOUNT RATE -  10 %; FUEL INFLATION RATE -  15 %

  BREAK - EVEN AT YEAR  5
```

A.6

GRAPHS & FIGURES

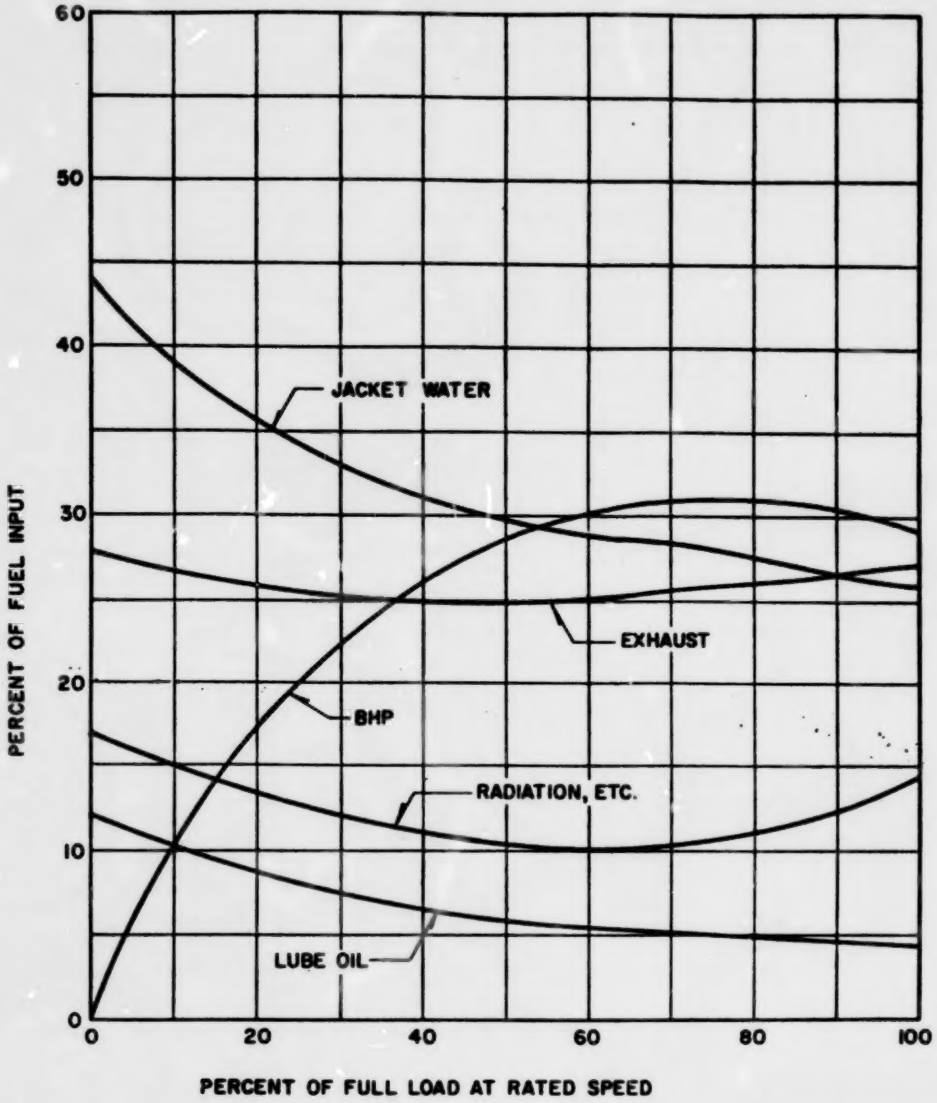
Excerpt from a 1980 study "An Inventory of Major Diesel Generating Systems in Canada and an Assessment of the Potential Markets for Heat Recovery"



TYPICAL GENERATOR EFFICIENCY

BASED ON ASHRAE SYSTEMS 1976 BY PERMISSION

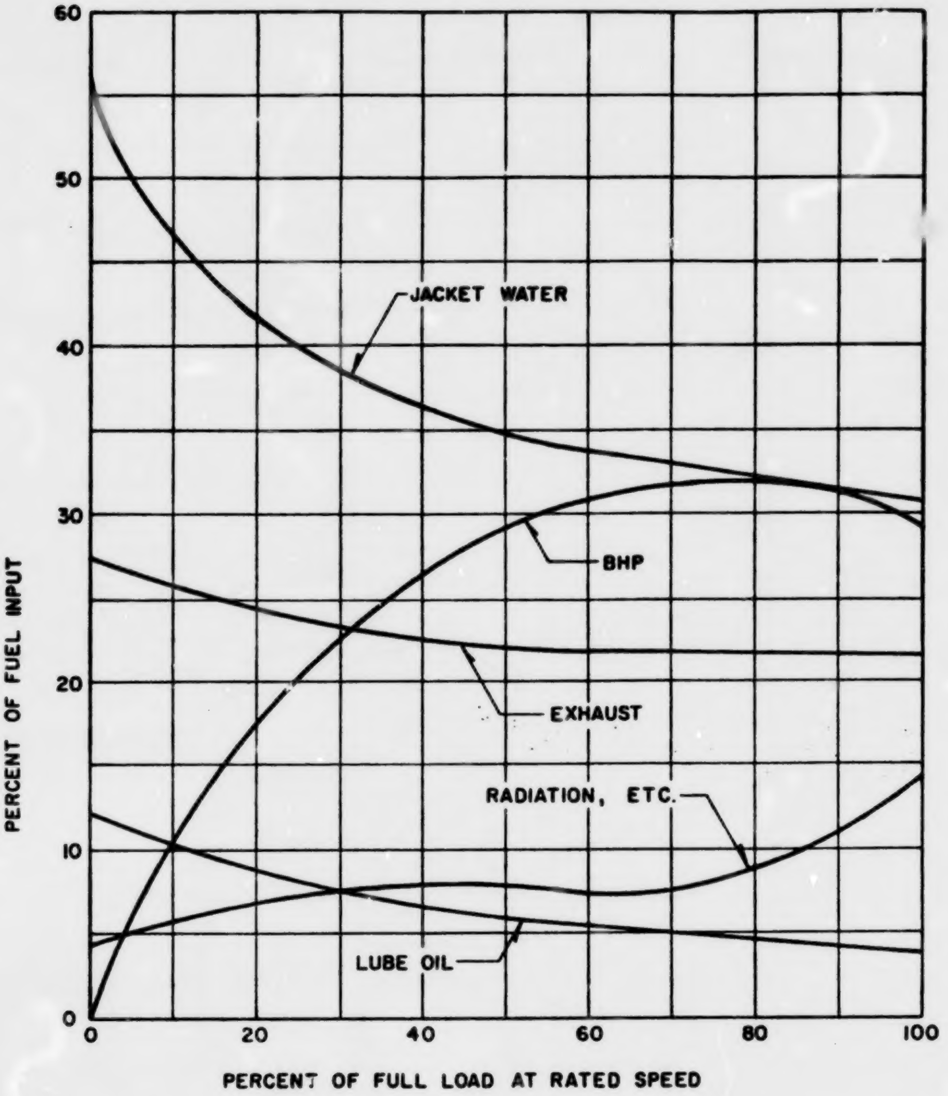
GRAPH IA



HEAT BALANCE FOR TYPICAL UNSUPERCHARGED ENGINE WITH HOT EXHAUST MANIFOLD

BASED ON ASHRAE SYSTEMS 1976 BY PERMISSION

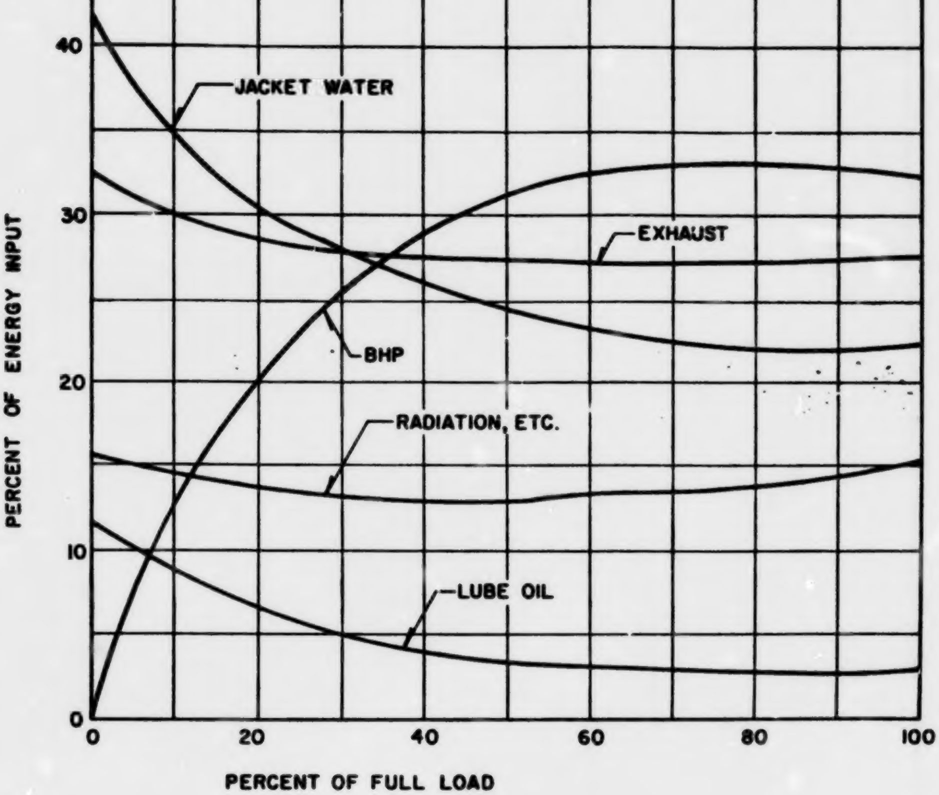
GRAPH 2A



HEAT BALANCE FOR TYPICAL UNSUPERCHARGED ENGINE WITH WATER-COOLED EXHAUST MANIFOLD

BASED ON ASHRAE SYSTEM 1976 BY PERMISSION

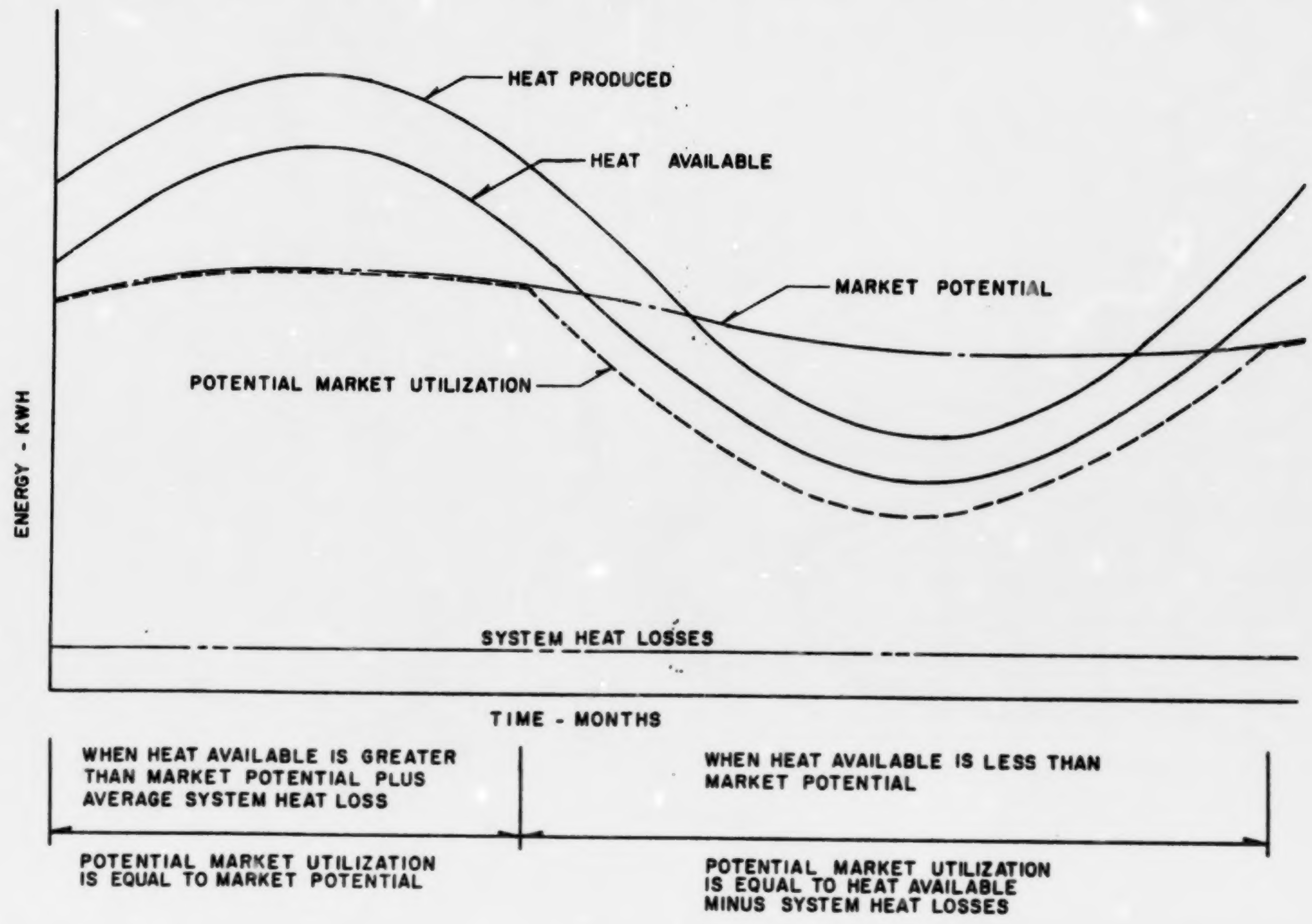
GRAPH 3A



HEAT BALANCE FOR TYPICAL TURBOCHARGED ENGINE

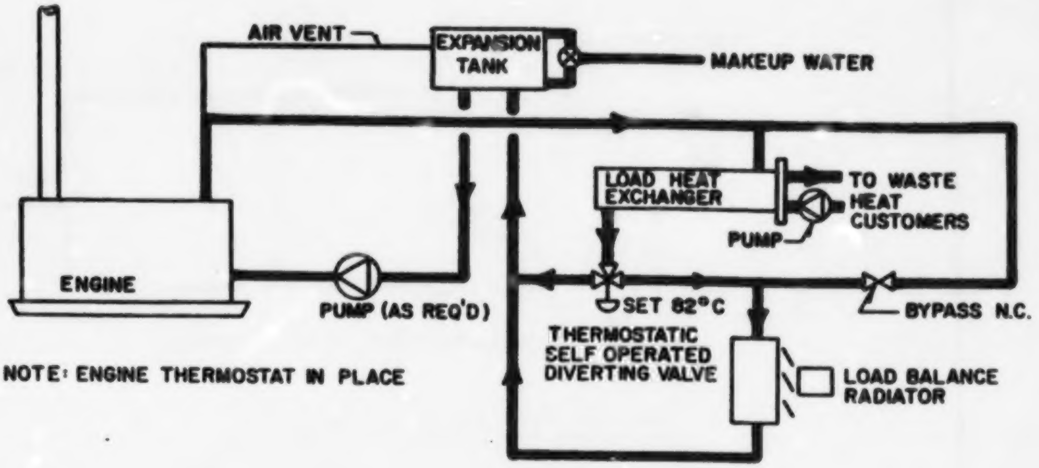
BASED ON ASHRAE 1976 SYSTEMS BY PERMISSION

GRAPH 4A



HEAT AND MARKET RELATIONSHIPS

GRAPH 5A

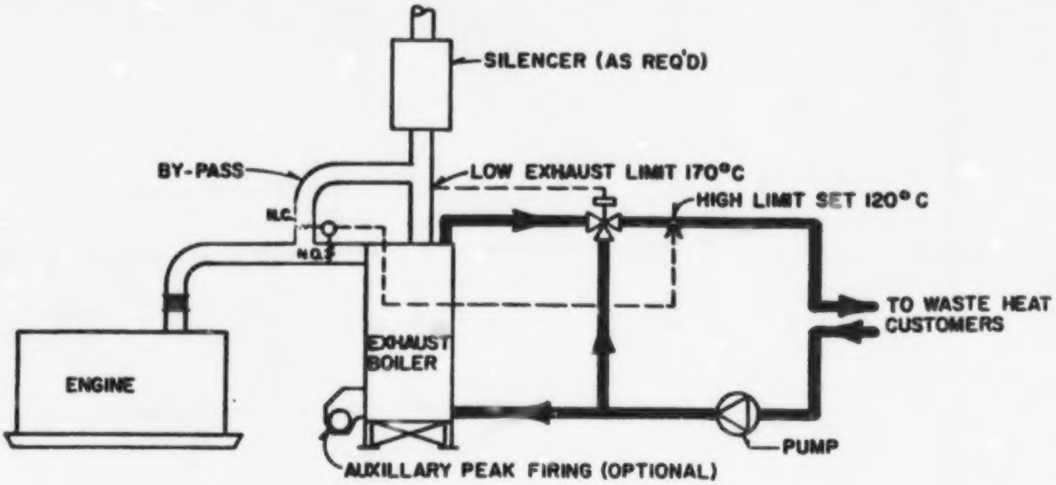

AIR VENT
EXPANSION TANK
MAKEUP WATER
LOAD HEAT EXCHANGER
TO WASTE HEAT CUSTOMERS
PUMP
ENGINE
PUMP (AS REQ'D)
SET 82°C
BYPASS N.C.
THERMOSTATIC SELF OPERATED DIVERTING VALVE
LOAD BALANCE RADIATOR
NOTE: ENGINE THERMOSTAT IN PLACE

SOLID WATER SYSTEM
JACKET RECOVERY ONLY

OPERATIONS:

THE ENGINE THERMOSTAT CONTROLS COOLANT FLOW IN THE LOOP. HEAT REJECTION TAKES PLACE IN THE LOAD HEAT EXCHANGER DEPENDING ON WASTE HEAT CUSTOMERS DEMANDS. WHEN THE LEAVING WATER TEMPERATURE FROM THE LOAD HEAT EXCHANGER IS LESS THAN 82°C, FLOW IS DIVERTED BACK TO THE ENGINE. FOR TEMPERATURES GREATER THAN 82°C, WATER DIVERSION IS TO THE LOAD BALANCE RADIATOR.

FIG. 1A


SILENCER (AS REQ'D)
BY-PASS
LOW EXHAUST LIMIT 170°C
HIGH LIMIT SET 120° C
N.C.
N.O.
EXHAUST BOILER
ENGINE
TO WASTE HEAT CUSTOMERS
PUMP
AUXILLARY PEAK FIRING (OPTIONAL)

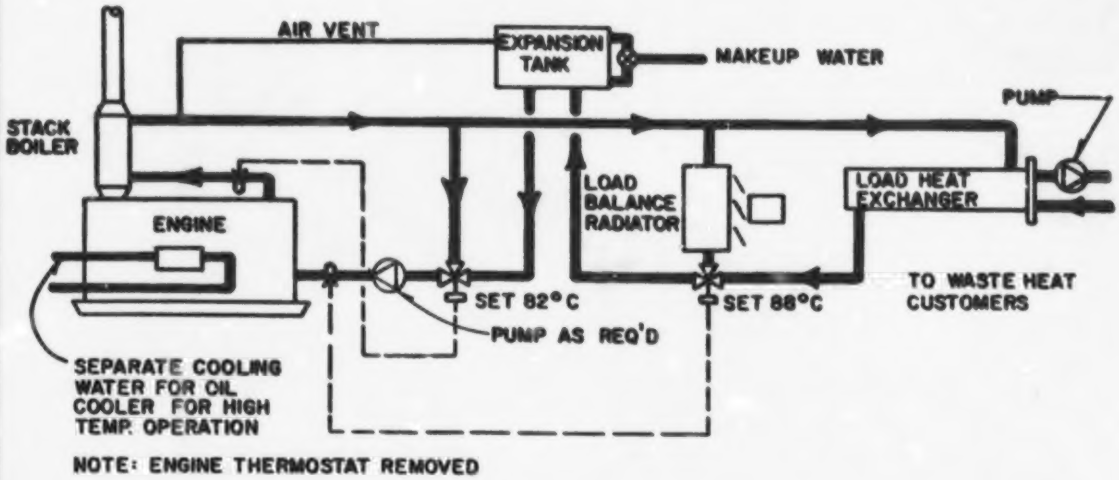
SOLID WATER SYSTEM
EXHAUST RECOVERY ONLY

OPERATION:

FLOW THROUGH THE EXHAUST BOILER IS GOVERNED BY THE LOW EXHAUST TEMPERATURE CONTROL SET ABOVE THE CONDENSATION TEMPERATURE OF THE GAS. TEMPERATURES BELOW 170°C WILL CAUSE THE THREE WAY VALVE TO BY-PASS THE BOILER TO REDUCE THE AMOUNT OF HEAT EXTRACTED. ABOVE 170°C, FULL FLOW IS THROUGH THE BOILER. WHEN CUSTOMER DEMAND IS LOW, THE HIGH LIMIT SET AT 120°C WILL BY-PASS EXHAUST GAS.

AUXILLARY PEAK FIRING IS SET TO OPERATE AT A MINIMUM SUPPLY WATER TEMPERATURE AND USUALLY ELIMINATES THE NEED FOR THE LOW EXHAUST LIMIT.

FIG. 2A

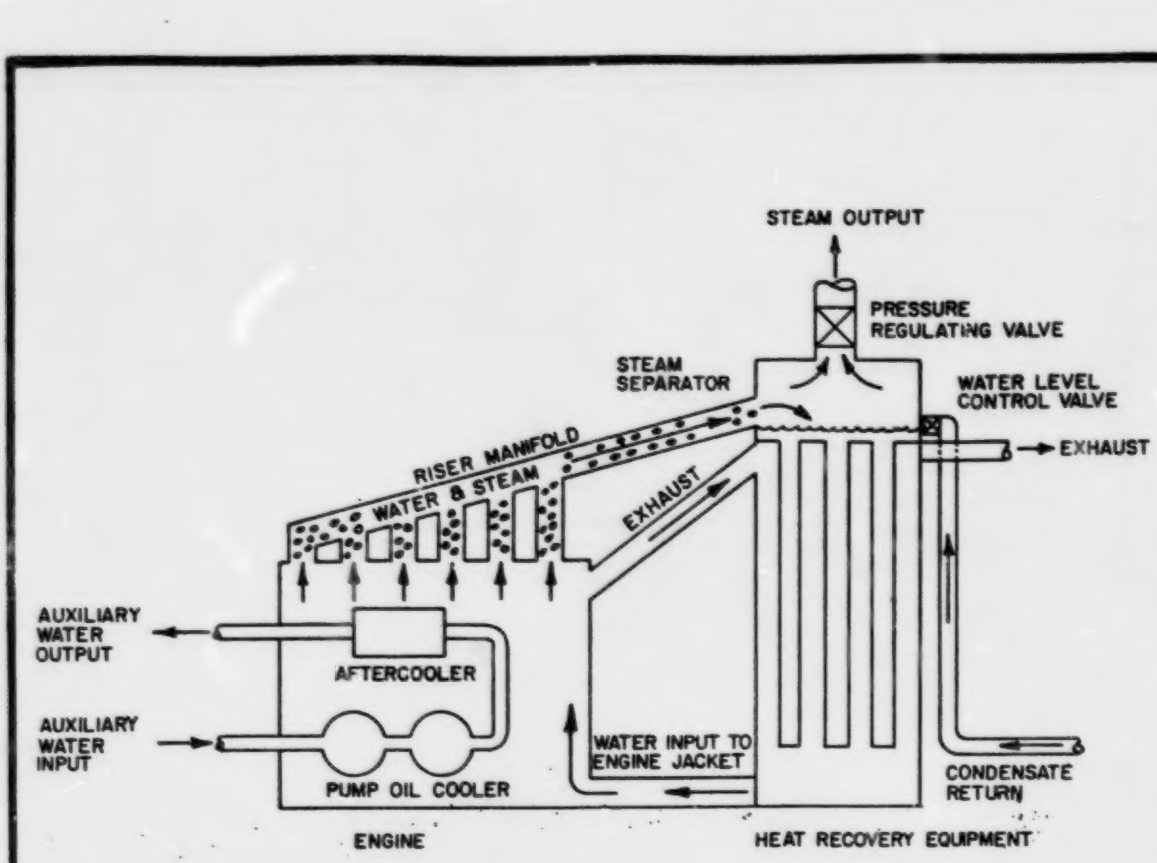

AIR VENT
EXPANSION TANK
MAKEUP WATER
PUMP
STACK BOILER
ENGINE
LOAD BALANCE RADIATOR
LOAD HEAT EXCHANGER
SET 82°C
SET 88°C
PUMP AS REQ'D
TO WASTE HEAT CUSTOMERS
SEPARATE COOLING WATER FOR OIL COOLER FOR HIGH TEMP. OPERATION
NOTE: ENGINE THERMOSTAT REMOVED

SOLID WATER SYSTEM
JACKET AND STACK RECOVERY

OPERATION:

TO PREVENT THERMAL SHOCK, FULL FLOW IS MAINTAINED THROUGH THE STACK BOILER BY REMOVING THE ENGINE THERMOSTAT. MINIMUM ENGINE TEMPERATURE IS MAINTAINED THROUGH THE THREE-WAY VALVE SET TO 82°C. IN CASES WHERE THE LOAD HEAT EXCHANGER DOES NOT ABSORB THE FULL ENGINE OUTPUT, THE THREE WAY VALVE SET TO 88°C WILL BLEND WATER THROUGH THE LOAD BALANCE RADIATOR UNTIL THE ENGINE RETURN WATER IS BELOW 88°C.

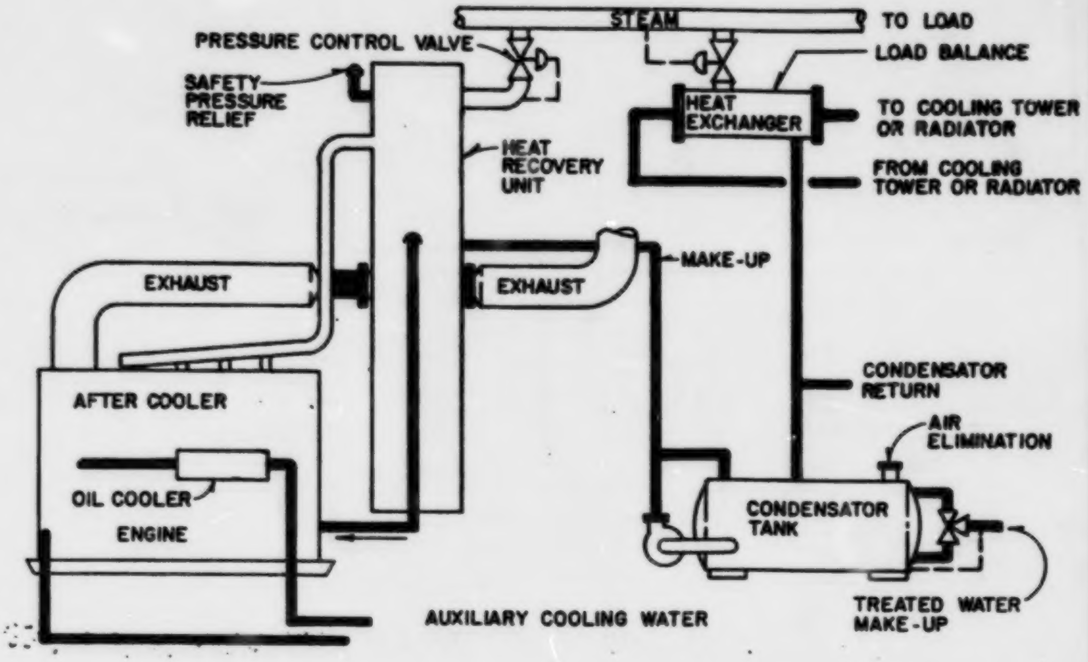
FIG. 3A


STEAM OUTPUT
PRESSURE REGULATING VALVE
STEAM SEPARATOR
WATER LEVEL CONTROL VALVE
EXHAUST
RISER MANIFOLD
WATER & STEAM
EXHAUST
AUXILIARY WATER OUTPUT
AFTERCOOLER
AUXILIARY WATER INPUT
WATER INPUT TO ENGINE JACKET
PUMP OIL COOLER
CONDENSATE RETURN
ENGINE
HEAT RECOVERY EQUIPMENT

THE EBULLIENT SYSTEM

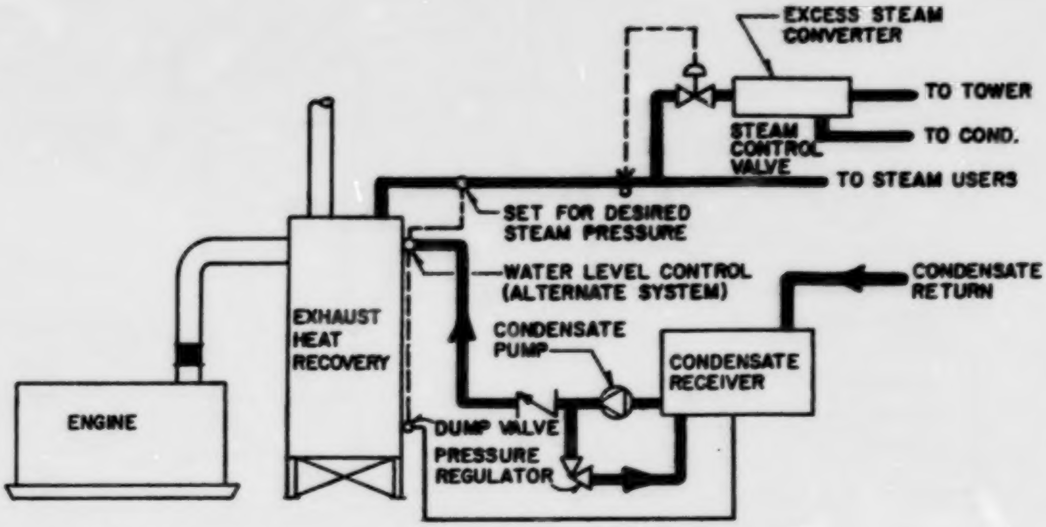
OPERATION OF THE EBULLIENT SYSTEM IS DESCRIBED IN SECTION 6.2.4 AND APPENDIX A.4

FIG. 4A


STEAM
TO LOAD
PRESSURE CONTROL VALVE
LOAD BALANCE
SAFETY PRESSURE RELIEF
HEAT EXCHANGER
TO COOLING TOWER OR RADIATOR
HEAT RECOVERY UNIT
FROM COOLING TOWER OR RADIATOR
MAKE-UP
EXHAUST
EXHAUST
CONDENSATOR RETURN
AFTER COOLER
AIR ELIMINATION
OIL COOLER
CONDENSATOR TANK
ENGINE
AUXILIARY COOLING WATER
TREATED WATER MAKE-UP

EBULLIENT SYSTEM SCHEMATIC

FIG. 5A


EXCESS STEAM CONVERTER
TO TOWER
TO COND.
STEAM CONTROL VALVE
TO STEAM USERS
SET FOR DESIRED STEAM PRESSURE
WATER LEVEL CONTROL (ALTERNATE SYSTEM)
CONDENSATE RETURN
EXHAUST HEAT RECOVERY
CONDENSATE PUMP
CONDENSATE RECEIVER
ENGINE
DUMP VALVE
PRESSURE REGULATOR

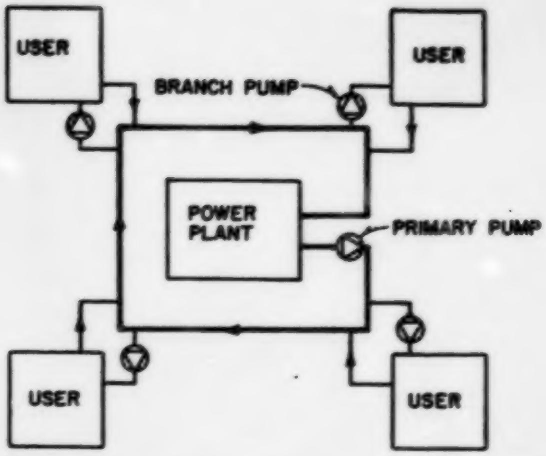
EXHAUST HEAT RECOVERY - STEAM

OPERATION:

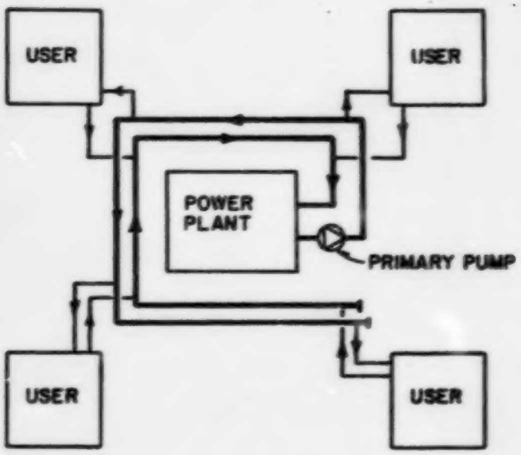
BACKPRESSURE ON THE EXHAUST RECOVERY IS CONTROLLED BY THE STEAM VALVE. DURING PERIODS OF LOW CUSTOMER USE, EXCESS STEAM CAN BE ABSORBED BY THE EXCESS STEAM CONVERTER, OR ALTERNATELY, BY LOWERING THE LEVEL OF WATER IN THE EXHAUST BOILER TO REDUCE THE HEAT EXCHANGER SURFACE AREA.

THE WATER LEVEL CONTROL IS APPROVED ONLY FOR VERTICAL EXHAUST BOILERS, SO THAT EXCESS STEAM CONVERTERS ARE MANDATORY ON HORIZONTAL BOILERS.

FIG. 6A


USER
USER
BRANCH PUMP
POWER PLANT
PRIMARY PUMP
USER
USER

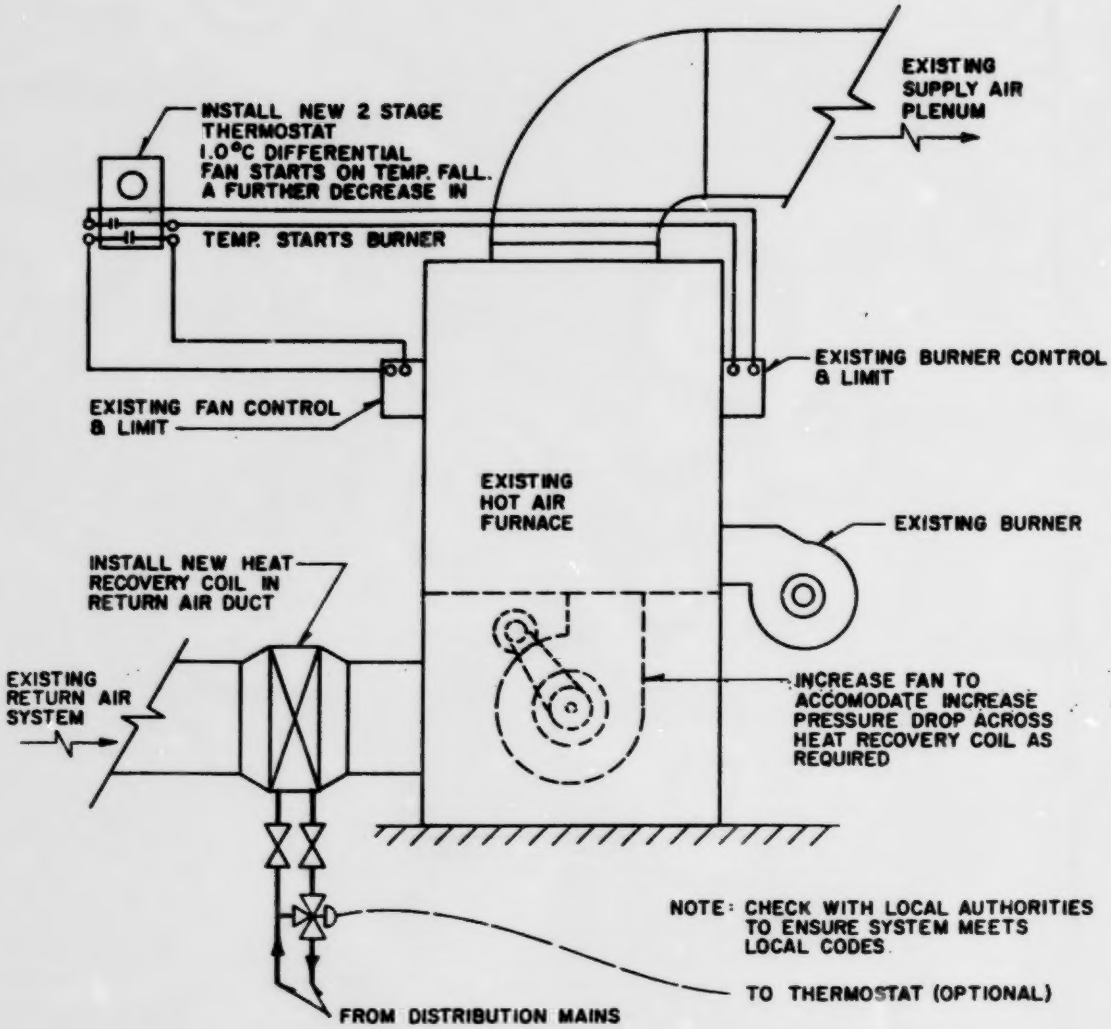
ONE PIPE DISTRIBUTION SYSTEM


USER
USER
POWER PLANT
PRIMARY PUMP
USER
USER

TWO PIPE DISTRIBUTION SYSTEM

ONE AND TWO PIPE MAIN DISTRIBUTION ALTERNATIVES
SOLID WATER

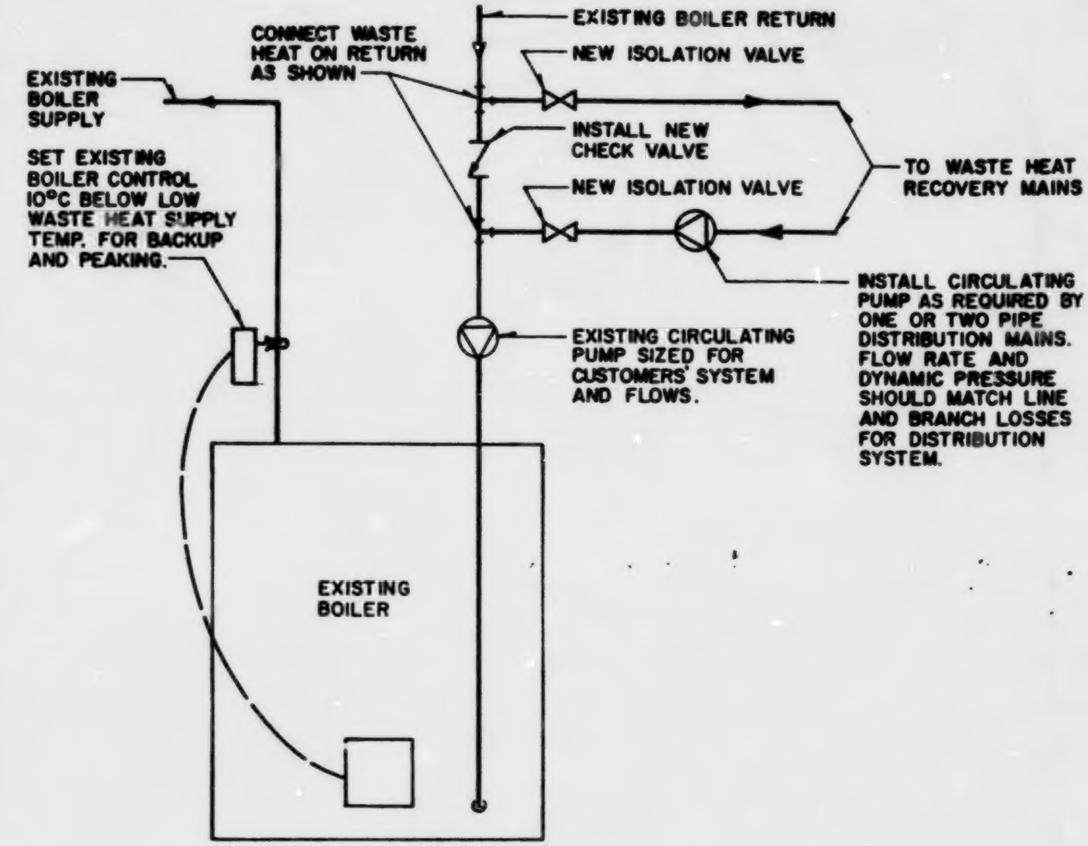
FIG. 7A


INSTALL NEW 2 STAGE THERMOSTAT
1.0°C DIFFERENTIAL
FAN STARTS ON TEMP. FALL. A FURTHER DECREASE IN
TEMP. STARTS BURNER
EXISTING SUPPLY AIR PLENUM
EXISTING BURNER CONTROL & LIMIT
EXISTING FAN CONTROL & LIMIT
EXISTING HOT AIR FURNACE
EXISTING BURNER
INSTALL NEW HEAT RECOVERY COIL IN RETURN AIR DUCT
EXISTING RETURN AIR SYSTEM
INCREASE FAN TO ACCOMODATE INCREASE PRESSURE DROP ACROSS HEAT RECOVERY COIL AS REQUIRED
TO THERMOSTAT (OPTIONAL)
FROM DISTRIBUTION MAINS

NOTE: CHECK WITH LOCAL AUTHORITIES TO ENSURE SYSTEM MEETS LOCAL CODES.

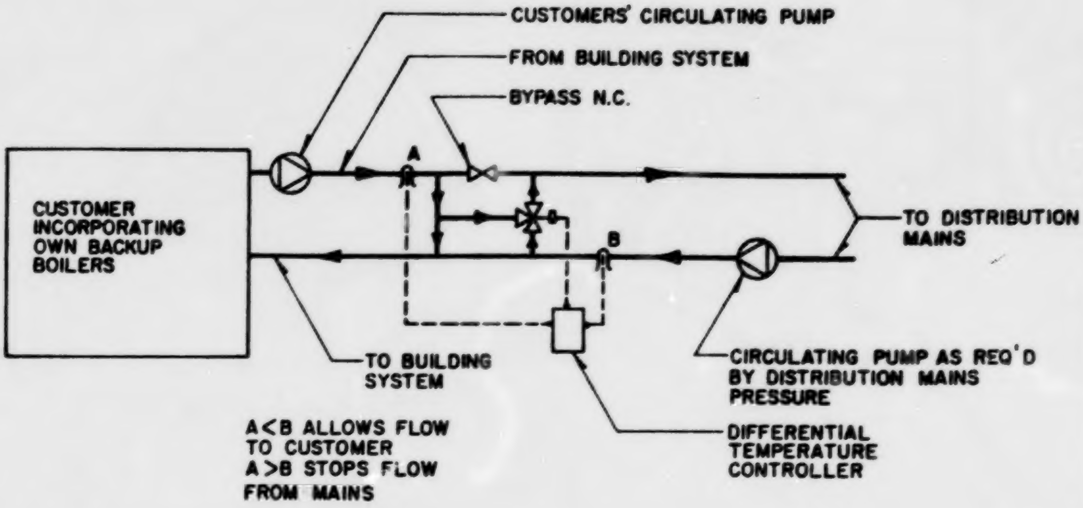
CONVERSION FOR HOT AIR SYSTEM, MAINTAINING EXISTING FURNACE AS BACKUP.

FIG. 8A


EXISTING BOILER RETURN
CONNECT WASTE HEAT ON RETURN AS SHOWN
NEW ISOLATION VALVE
EXISTING BOILER SUPPLY
INSTALL NEW CHECK VALVE
TO WASTE HEAT RECOVERY MAINS
SET EXISTING BOILER CONTROL 10°C BELOW LOW WASTE HEAT SUPPLY TEMP. FOR BACKUP AND PEAKING.
NEW ISOLATION VALVE
INSTALL CIRCULATING PUMP AS REQUIRED BY ONE OR TWO PIPE DISTRIBUTION MAINS. FLOW RATE AND DYNAMIC PRESSURE SHOULD MATCH LINE AND BRANCH LOSSES FOR DISTRIBUTION SYSTEM.
EXISTING CIRCULATING PUMP SIZED FOR CUSTOMERS' SYSTEM AND FLOWS.
EXISTING BOILER

TYPICAL BOILER MODIFICATION TO WASTE HEAT RECOVERY

FIG. 9A


CUSTOMERS' CIRCULATING PUMP
FROM BUILDING SYSTEM
BYPASS N.C.
A
B
CUSTOMER INCORPORATING OWN BACKUP BOILERS
TO DISTRIBUTION MAINS
TO BUILDING SYSTEM
CIRCULATING PUMP AS REQ'D BY DISTRIBUTION MAINS PRESSURE
DIFFERENTIAL TEMPERATURE CONTROLLER
A<B ALLOWS FLOW TO CUSTOMER
A>B STOPS FLOW FROM MAINS

CONTROL ARRANGEMENT USED TO PREVENT CUSTOMER FROM SUPPYING HEAT TO MAIN DISTRIBUTION SYSTEM

FIG. 10A

A.7

TECHNICAL DISCUSSION

Diesel Generating Heat Recovery Systems

A.7 TECHNICAL DISCUSSION - DIESEL GENERATING HEAT RECOVERY SYSTEMS

DIESEL ENGINES

Diesel engines are available in sizes up to about 16,000 brake horsepower and can be fueled by a wide range of petroleum products of which #2 fuel oil is most popular. The engines are also fired with natural gas in combination with pilot liquid fuel.

Operating speeds of diesel engines usually vary from less than 600 RPM to 1,800 PRM, depending on size, generator characteristics and design time between overhauls, which normally vary from a minimum of 20,000 to 30,000 hours.

GENERATORS

Generators are matched to the prime movers by considering the efficient operation of both. Generator efficiency is a non-linear function of load as described by Graph 1.

HEAT RECOVERY

The amount of heat rejected will vary depending on engine design. Graphs 2A, 3A & 4A describe typical heat balances for common engine configurations.

Exhaust temperatures for the four stroke engines are approximately 650°C at full load and 550° at 60% load. Two cycle engines operate at lower exhaust gas temperatures, especially at light loads due to the scavenger air volumes. The lower temperature gas ranges from 375°C at full load to 250°C at low loads. This high volume low temperature gas offers less efficient exhaust gas heat recovery possibilities.

JACKET HEAT CONSIDERATIONS

As stated previously, water cooling circuits in the block and exhaust manifolds must remove about 30% of the heat input to the engine. With engine operation at temperatures of above 80°C condensation from combustion products should not be a problem. Engines operating at 120°C and 200 kPa have modified gaskets and seal design so that they operate satisfactorily at these temperatures. Maximum engine temperature variation through the engine should be limited to 10°C to avoid thermal stress and flow rates should be kept within manufacturer's design limits. Circulation pumps may be engine mounted and driven or electric and remote. For elevated temperature operation, the pumps should have modified seals to work satisfactorily.

Engine castings may crack if exposed to sudden cooling such as a large process or intermittent heating load that temporarily overloads the system. Storage tanks provide an excellent buffer for such cases where water systems are involved.

For steam systems, a back pressure regulator is used to keep engine temperatures uniform. In the ebullient system, where fluid density variations induce flow through the engine, very little temperature difference exists between inlet and outlet. It is extremely important that precautions are taken to ensure backpressure is maintained at all times as a sudden loss in pressure will result in steam bubble expansion in the engine which would interfere with circulation and result in overheating of critical engine areas.

The ebullient system requires that engine coolant passages be arranged for gravity circulation and free ejection of bubbles of steam. The typical arrangement is to slope engine coolant passages upward to encourage gravity flow and permit free release of steam to the separator.

The free convection cooling system is less dependent on mechanical accessories and is more readily arranged for completely independent assembly of each engine with its own coolant system.

EXHAUST GAS RECOVERY

The practical limitations of exhaust heat transfer equipment is based on a recommended maximum exhaust temperature of 120°C. Depending on the initial temperature, 50 to 60% of the available exhaust heat can be recovered.

Recovery boilers should be designed for easy removal of soot on the exhaust side and an ability to clean the water side. The boilers can also be used as surge tanks, steam separators and fluid regulators.

The recovery equipment must not have an adverse effect on the engine's ability to do work. A prime consideration is the backpressure imposed on the engine exhaust. Limiting backpressures vary widely with the make of engine, but in general the range is 150 mm water gauge.

Heat recovery silencers are designed to ba adapable to most engines, with efficiency determined by the initial exhaust temperature and heat transfer surface.

There is very little data available on the effect of water vapour in the exhaust gas. However, a simple equation can be applied to determine quantitively the feasibility of heat recovery application for any given engine:

$$Q = W \times .003 (T_1 - 150)$$

where Q = heat recovery, kW
W = exhaust flow, kg per hour
T_1 = exhaust temperature, ^oC

specific heat of gas = $.0003\ kW/_{kg} - C$

If engine data is not available, an approximatation of .29 kW of heat per horsepower can be used.

The design of heat recovery boilers should be in accordance with the ASME Code for the working pressure required. Since the temperature levels in most exhaust systems are not excessive, it is common practice to use flange or firebox quality steel for pressure parts, and low carbon steel for the non-pressure components. Wrought iron or copper may be used to improve heat transfer capacities.

LUBRICATING SYSTEM

The operating temperature of the engine affects the proportion of heat removed by the lube oil. In addition, the temperature of the lubricant must remain between 70^{0} and 90^{0}C with longer life expected at lower temperatures.

Engine manufacturers usually size their oil cooler heat transfer surfaces on the basis of 55^{0}C entering coolant water and without provision for additional heat gains to the lubricant that occur with high engine operating temperatures. For applications where jacket water temperatures exceed 105^{0}C, the economical temperature for recovered heat from the oil cooler is about 70^{0} minimum.

Raw water should be avoided for use in oil coolers unless it is free of silt, calcium carbonates, sand or other contaminants. A domestic water heater may be installed on this circuit to provide a reserve heat exchanger.

In northern applications, utilidor domestic water recirculation heating lines offer an opportunity to use oil cooler heat due to the low grade required.

TURBOCHARGERS

Turbocharging on diesel engines permit more air to be forced into the cylinders so that larger quantities of separately injected fuel can be burned. Since the gas and air mixture will ignite at some specific temperature, pressure relationship, the lower the inlet air temperature, the higher the compression ratio can go before spontaneous combustion (pre-ignition) occurs.

For this reason aftercoolers are used to reduce the turbo charger outlet air temperature before entering the cylinders. Generally, water at 30°C is used for this application and is a premium coolant because of the volumes and low temperature required.

GENERAL INSTALLATION PROBLEMS*

Cleanliness of the circulating fluid systems is necessary because the internal coolant passages of the engine are not readily accessible for service. The installation of piping, heat exchangers, valves and accessories must include provisions for internal cleaning of these ciruits before they are placed in service. Coolant fluids must be non-corrosive and free from salts, minerals or chemical additives that will deposit on hot engine surfaces or that will form sludge in relatively inactive fluid passages. In general, engines cannot be effectively drained and washed internally without major disassembly, so any chemical treatment of the coolant fluid that produces sediment or sludge is undesirable.

As an inital step toward maintaining clean coolant surfaces, it is necessary to severely limit fresh water makeup. The coolant system should be tight and free from leaks. Softened water of mineral free water is effective for initial fill and makeup. Forced circulation hot water systems may require nothing more than minor corrosion inhibiting additives to assure long, trouble-free service, and this feature is one of the major assets of hot water heat recovery systems.

The ebullient cooling method offers some special hazards for water treatment. Evaporation takes place in the engine and the concentration of dissolved minerals will increase at this critical location.

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This problem can be minimized by encouraging high flow rates, with gravity or forced cirulation, and by reducing to a negligible value the addition of minerals into the system. In any case, the water treatment must be adequate to prevent corrosion from free oxygen brought in with returned condensate and makeup water. Additional treatment should control corrosion in the heat recovery muffler and steam separator and in the condensate system. If the cost of pumping the water and the discount in utilization temperature can be absorbed in the system design, a hot water system is indicated as first preference. Most of the engines now available were designed for forced circulation of the coolant.

Where several engines are used in one process, independent coolant systems for each machine must be provided to avoid a complete plant shutdown from a common coolant system component failure. Each unit is a separate package with its own controls, heat exchangers and makeup system. Such independence also leads to possible disadvantages in that the unused engines will not be maintained at operating temperature, as is the case when all units are in a common circulating system. If the idle machine temperature drops below the dew point of the products of combustion, corrosive condensate will be formed in the exhaust gas passages each time the idle machine is started. When the volume of water and weight of machinery that must be heated up to operating temperature is large, the volume of condensate is quite significant and some method of draining the condensate is necessary. Some contaminants will get into the lube oil and reduce the service life.

If the machinery gets very cold, it may be difficult to start. Where units are started and stopped with some frequency, it is desirable to provide some off-cycle heating sequence to lessen the exposure to corrosion.

Water level control of separate engine cooling systems that produce steam must take into account the possibility of back flow through the steam nozzle of units that are out of operation. Each machine system may be equipped with a back pressure regulating valve or some form of steam check valve or equalizing line to avoid this difficulty.

Analysis of the current problems of installation costs, available product designs and operating experience indicated that forced circulation hot water heat recovery systems are best suited to installations of about 1000 kw total capacity or smaller and where future expansion is limited by other design considerations. In those projects of much larger capacity, the fluid pumping systems become unwieldy, and making provisions for considerable future increase in capacity is quite difficult. These larger projects are likely to be better served with free convection, ebullient cooled packages for each engine, with a low pressure steam headed connecting the various sources of heat input to the utilization loads. Special water conditioning and testing apparatus can be provided on larger projects and the added complexity of coolant quality control in the steam systems may be readily justified by the greater realiability of the independent engine coolant systems.

A.8

CAMBRIDGE BAY N.W.T.

A Description Written in 1980,
of a Typical Waste Heat
Retrofit Project.

DESCRIPTION OF A TYPICAL COMMUNITY WASTE HEAT RECOVERY RETRO-FIT PROJECT: CAMBRIDGE BAY, N.W.T.

GENERAL

The object of this Appendix is to outline the typical technical, financial and administrative considerations to be addressed to complete a cooperative community waste heat recovery retro-fit project.

BACKGROUND

Motivation for the Government of the Northwest Territories (G.N.W.T.) and Northern Canada Power Commission (NCPC) to consider diesel generator waste heat retro-fit was precipitated by the rise in fuel prices during the seventies. Since most of the communities throughout the N.W.T. derive electrical energy from fossil fuels, it is apparent that the north faces a certain operational cost vulnerability for which there are no realistic alternatives for the forseeable future.

As part of a comprehensive look at energy conservation, the G.N.W.T. decided to study the possibility of waste heat recovery from community generating plants in 1976. The emphasis was to be on retro-fit of existing buildings and equipment.

PRE-DESIGN INVESTIGATION

The preliminary work centered around potential site selection and recovery techniques to be used. The intent was to view the project as an experimental pilot system on which to base future conversions.

From the beginning, it was apparent that the project depended on the supplier (NCPC) and the user (G.N.W.T.) reaching a satisfactory arrangement technically, administratively and financially. The supplier and user had different and sometimes conflicting interests. NCPC wanted to protect their engines, keep maintenance costs down, and eliminate system complications. The G.N.W.T. wanted high grade heat to minimize distribution and conversion costs and a guaranteed supply of heat. It was therefore important to realize a mutually acceptable design for both parties, even if it meant compromising the most efficient technical solution. The site selection for Cambridge Bay reflects this approach.

The choice represented the types of building conversions likely to be undertaken in future: hot air, hot water, external piping between buildings, below grade, above grade and across roadways.

PRELIMINARY DESIGN

During the preliminary design stages, it was decided to utilize only the engine coolant water heat and not the exhaust gas heat. The decision was based on four considerations.

1) As a pilot project, we wanted to use the lower grade heat to obtain operating data on a simple form of recovery.

2) The total building requirements could be handled by the rejected coolant heat alone.

3) The capital cost per BTU/annum was lower for engine coolant recovery only. It was also technically straightforward.

4) NCPC felt that "coolant only" recovery would not affect engine performance nor require changes to their basic method of operating.

The buildings connected to the system were known to be uncomfortable, drafty and very heavy fuel users, consuming in excess of 50,000 gallons per annum. To keep the project results in context, no building retro-fitting was allowed until at least one year of operating data was obtained.

DESIGN

It was agreed with NCPC that "in-plant" modifications would follow those outlined previously in Figure (1A) of this report. This decision set the system distribution water temperature at 70°C and was used in the design of the various building retro-fit requirements. Distribution mains were sized in accordance with the required flows and pressure drops for the network.

The main garage houses the main distribution pumps for the system. Since the garage had hot water boilers originally, connection to the system was made according to Figure(9A). As the waste heat supply temperature was lower than the existing design, one extra unit heater was included to provide the same level of heating.

The supply warehouse was heated by a large hot air furnace which was modified in a manner similar to Figure(8A) with an additional three way valve to control the supply air temperature on a continuously operating fan. In the event of insufficient heat, an end switch on the thermostat starts the burner. In addition, one unit heater was added near the main loading door for pickup purposes.

The tradeshop was connected in a manner similar to the main garage.

Both boilers are capable of maintaining the distribution system at design temperatures in the event of inadequate heat from NCPC.

The vehicle storage and carpenter shop were originally heated by hot air furnaces left in place to act as backup. These buildings were retro-fitted with sufficient overhead unit heaters to maintain temperature via the recovery system.

The system was filled with 50% glycol, a normal practice for Arctic installations. As the soils were thaw-stable, outside mains were shallow buried with factory applied insulation. Due to the difficulty of arranging welding in Cambridge Bay, it was decided to use mechanical grooved pipe with special gaskets for hot glycol application covered with urethene half shell insulation and heat shrink sleeves per Figure (11_A). Using this system, no expansion service loops were required. Makeup water and system expansion were included in the design in accordance with good engineering practice.

SYSTEM EXTENSIONS

The system is being expanded to include heating of the municipal water supply and a new community office complex. The extension will remain as a hot water system and may require an expansion of the in-plant recovery system. Maximum use can be made of the extra waste heat available.

COST/BENEFIT ARRANGEMENTS

The responsibility for the system was broken down as follows:

1) All modifications and maintenance behind the powerhouse wall were the responsibility of NCPC.
2) The distribution lines, pumps and equipment from the powerhouse wall were the responsibility of the G.N.W.T. for cost and maintenance.

Because NCPC and the G.N.W.T. would both benefit from the recovered heat through increased cash flow or cost avoidance, it was agreed to have the G.N.W.T. pay 50% of the equivalent fuel cost for the heat received and used.

Subsequent heat recovery projects, such as Rankin Inlet have a different financial arrangement. NCPC requires the customer to pay 100% of the capital modification costs for heat recovery including in-plant modifications and 50% of the equivalent fuel value of heat recovered. In return, NCPC allows for "free heat" for a period of time which will help amortize the customers capital investment.

SUMMARY

Now that the pilot project has been in operation for over two years, it is evident that the system requires very little attention, performs as predicted and has received unqualified acceptance from both NCPC and the Government of the Northwest Territories at the local level.

A review of the capital costs show that the entire system was installed for approximately $120,000 including in-plant modifications and building connections.

Heat produced and utilized was equivalent to approximately 50,000 gallons of fuel oil annually at a cost F.O.B. Cambridge Bay of $1.35 per gallon in 1977, resulting in a gross system payout of approximately two years.

A.9

WASTE HEAT RECOVERY

Conversion Equipment and Distribution Systems.

WASTE HEAT RECOVERY CONVERSION EQUIPMENT

GENERAL OVERVIEW

The various types and combinations of waste heat recovery equipment and systems used in cogeneration design must be considered for technical, economical and practical reasons. Once the method has been decided, the following criteria will take precedence over all heat recovery considerations:

1. Engine operating temperatures and pressures must be maintained within acceptable limits regardless of the downstream demand for recovered heat.

2. Waste heat distribution system failures must occur in a manner that will neither harm the engine nor jeopardize the ability of the plant to produce electricity.

Heat recovery methods are generally grouped into normal temperature (90°C) and high temperature (120°C). High temperature methods can be further divided into hot water systems (120°C and 130 kPa pressure) and ebullient systems (120°C and 100 kPa pressure).

NORMAL TEMPERATURE RECOVERY

JACKET WATER RECOVERY

Normal jacket water recovery is essentially low-grade heat, usually supplied to the customer at 75°C when exchanger losses are considered. Slightly higher temperatures are possible; however the size of the heat exchanger becomes prohibitive to achieve temperatures which closely approach that of the engine coolant.

In retro-fit applications, very little floor space is required for heat exchanger installations. Because of this, most existing plants can accommodate the modification without problem. It is possible to connect more than one engine per heat exchanger, although most operators prefer to duplicate the engine cooling systems.

Costs for "jacket water only" recovery vary from $40 to $60 per kilowatt depending on the size and geographical location of the retro-fit. Figure (1) describes a typical jacket waste system.

EXHAUST RECOVERY - NORMAL TEMPERATURE

Exhaust heat recovery equipment is designed to recover heat from the exhaust gas down to a temperature of about 170°C , which is above the condensation temperature of the gas stream.

Because of the corrosive nature of the exhaust gases, some designs have provision for maintaining the minimum outlet temperature such as by-passing some coolant across the boiler.

An exhaust boiler system offers a convenient opportunity to employ auxiliary firing in the unit to supplement the system heating requirements when the demand exceeds the ability of the total energy system to supply.

It is recommended that each engine be equipped with its own exhaust boiler or heat recovery silencer. Experience has proven that it is very difficult to manifold several exhaust systems together and still maintain effective isolation of any engine not on the line.

Costs for exhaust recovery may vary from $80 to $120 per kilowatt depending on the size, location, and space requirements. Figure (2) describes a typical exhaust boiler system.

COMBINED JACKET WATER AND EXHAUST RECOVERY - NORMAL TEMPERATURE

The addition of exhaust gas recovery to jacket water complicates the flow and controls slightly over either the simple jacket water or exhaust gas recovery.

Additional consideration must be given to the situation where the demand for waste heat is minimal while the engine is operating near load capacity. Because of the additional heat which must be rejected due to stack recovery, the retro-fit must also consider the requirements to keep the system within acceptable operating limits. This may mean the addition of supplementary radiators to the system either on the primary engine side or the secondary distribution network, or the inclusion of an exhaust by-pass pipe as shown in Figure (2A).

The advantage of combined recovery is that overall plant efficiencies can approach 75% if a sufficient market exists for the recovered heat. In addition, the distribution water temperatures coincide with those normally used in hot water system design (95°C) resulting in smaller distribution main sizes and lower pumping rates than with jacket water alone.

Costs for the combined jacket water and exhaust recovery normal temperature systems vary from $60 to $90 per kilowatt depending on size, location and space considerations. Figure (3A) describes a typical combined system.

HIGH TEMPERATURE - SOLID WATER SYSTEMS

This system uses elevated jacket coolant temperatures up to 120°C at the engine outlet and operates as a normal temperature hot water system except for the additional pressure required in the circulatory systems and engine coolant circuit to prevent the formation of steam.

Consideration must be given to the engine design to allow for elevated temperature operation in terms of gaskets, seals, coolant pumps and oil cooling requirements. In general, conventional water pumps and engine gaskets will not be suitable for this service and supplemental oil cooling will be required if not so equipped.

The advantage of high temperature recovery lies in the higher quality of heat produced to the distribution system, which reduces distribution costs and allows for some process application in terms of potential markets.

Because the high temperature systems operate close to the design limits of the engines, greater care is required in terms of safety shut down systems, maintenance levels and supervision of the engines' vital signs. In retro-fit applications for engines not fitted for such operation, it is unlikely that the average plant operator will look favourably upon high temperature recovery.

Conversion costs to high temperature recovery may be higher than those for normal temperature because of the possible requirement for engine retro-fit. Estimates range from $100 to $120 per kilowatt depending of size, location, and space consideration.

EBULLIENT SYSTEMS

This system utilizes the heat of vaporization to remove rejected heat from the engine. The steam is moved through the water passages along with high temperature water by thermal action to a steam separator located at an elevation somewhat above the engine. No jacket water pump is required with this system as flow is maintained by the change in coolant density as it gains heat from the engine. Most of the heat gain is added in the form of heat of vaporization. Figure (4A) illustrates the process.

A number of arrangements are possible, the most common being an exhaust gas boiler and steam separator combined into a single package unit for each engine. Figure(5A) shows a typical system arrangement.

The ebullient system requires special consideration for the engine gaskets, and seals as well as special sloping header manifolds to collect the vapour at the top of the engine to ensure steam cannot be trapped in the engine.

The main advantages of ebullient systems are:

1) smaller distribution lines and heat rejection devices,
2) less expensive to control,
3) less parasitic power required to circulate coolant through engine jackets, and
4) higher grade of heat for process application; especially the mining industry.

The disadvantages of the ebullient systems are:

1) oxygen entering through open vents and makeup water to replace lost condensate contaminates the system. Scale formation can result causing both hot spotting and thermal distortion of cylinder lines and jackets,
2) fast acting back pressure valves are required to maintain a constant fluid/steam level above the engine regardless of steam consumption, and
3) steam systems may require that the plant operator maintain a stationary engineer with a steam ticket to service and operate the recovery equipment.

From a practical point of view, ebullient systems will not normally be preferred by the average plant operator for retro-fit application.

Costs for converting a conventional diesel plant to the ebullient system may vary from \$150 to \$250 per kW depending on size, type, location and space considerations.

EXHAUST RECOVERY ONLY - STEAM

Exhaust recovery equipment for steam production is similar to exhaust equipment used for solid water.

The advantage of steam production from exhaust is the high quality of heat which can be produced for process application. As the pressure of the supplied steam increases, the recovery efficiency and volume of steam decreases.

Aside from a slight decrease in engine performance due to increase exhaust back pressure, exhaust recovery does not normally require engine modifications to implement. Provisions must be made to reject surplus production when engine heat output exceeds demands from the system. Conversely, peaking steam boilers may be required when demand exceeds supply.

As with the ebullient system for jacket recovery, makeup water required treatment to prevent boiler systems fouling.

Figure (6A)shows a typical steam only exhaust recovery system.

DISTRIBUTION SYSTEMS

GENERAL OVERVIEW

Distribution systems begin at the outlet of the heat recovery devices and include the main distribution lines, expansion tanks, valves, controls, pumps, makeup system, branch loops, terminal dissipation apparatus and fuel fired auxillary heat input equipment used as part of the system. Distribution systems can be classified as:

1) Water
2) Steam
3) Combination, Steam/Water

Design considerations for waste heat distribution systems are similar to those encountered in conventional district heating systems.

WATER SYSTEM

The distribution mains to the users from the generating plant can be a one pipe or two pipe system as outlined schematically in Figure (7A).

ONE PIPE SYSTEMS

One pipe systems will generally service more customers with less main piping for a typical community.

CONSIDERATIONS - WATER SYSTEMS

The preferred method for retro-fit energy recovery is solid water systems, as the modifications are usually within the existing engine operating parameters.

Sizing of the distribution piping is done in accordance with standard engineering practice for the fluid used, which may be water, or a water/glycol solution if a danger of freezing exists. Based on the line sizes, circulating pumps are chosen in relation to the heat transported and the maximum temperature drop acceptable to the customers.

An analysis should be carried out to define the requirement for peak load heating capacity or buffer heat storage tanks on the main system. Emergency backup heating in the event of distribution line failure should be maintained by the users. It is normal for the customers' original heating system to be incorporated as part of the retro-fit. Figures (8A) and (9A) show typical retro-fit applications for a forced air furnace and a boiler installation. Additional unit heaters and convector radiation may be added to existing systems where the waste heat supply water temperatures are below the original building design values.

STEAM DISTRIBUTION SYSTEMS

Steam waste heat distribution systems are similar to district heating steam systems incorporating a steam line and condensate return.

Consideration must be given to collecting and returning the condensate and providing traps at the system low points. Peaking ability must be included either in the primary exhaust recovery boiler or along the distribution line. The advantage of steam distribution is the small line sizes which can be used in comparison to solid water systems. A disadvantage in some locations is the vulnerability to freezing if interruption should occur for a period of time. In addition, steam lines may require the services of steam fitters to operate.

COMBINATION STEAM/WATER SYSTEMS

In some cases it may be advantageous to supply heat from the plant via steam line to a central location and convert the heat to a hot water system for local distribution. This allows process steam to be available for special applications while eliminating the need for an elaborate condensate return network.

Depending on the customer/supplier relationship, it may be necessary to ensure that the customers' boilers do not supply heat to the main system during periods of low supply temperatures from the diesel plant. (This possibility exists where peaking boilers are not incorporated in the main system and the heat production is at a low point.)

Figure (10A)outlines the typical control arrangement used to prevent such reverse heat transfer.

If an agreement can be made with the heat supplier, it is advantageous from a capital cost point of view to incorporate all customer boilers on the system as peaking boilers feeding heat into the mains. In some cases, the customers' original boilers are sufficient to carry the entire distribution network in the event of a failure of the plant waste heat recovery equipment.

Appendix A.8 is a report on a solid water waste heat recovery system designed in 1976 as a pilot project in Cambridge Bay, N.W.T. to assess the feasibility of retro-fitting existing buildings to waste heat recovery from a nearby diesel generating plant. This system has been operational for two and one half years and is jointly owned by NCPC and the Government of the Northwest Territories.

PIPING MATERIALS AND METHODS

Although significant advances have been achieved in the design of polyethylene and plastic pipe, their properties remain severely restricted at normal operative pressures and temperatures encountered in distribution mains. However, extensive use is made of polyethylene tubing for customer in-slab heating where water temperatures are limited to a maximum of 30°C. In such applications, the tubing is very effective both from a cost and performance point of view and is capable of using low grade supply temperatures.

Steel pipe remains the choice for distribution systems discussed in this report. The amount and type of insulation used depends on ambient temperatures, system supply temperatures, the amount of heat surplus to market demand which can be wasted through line loss, and the minimum acceptable supply temperature for the most remote customer.

For supply water temperature of 95°C and lower, polyurethene insulation is normally used with a protective high density polyethylene outersheath for underground application. The above ground system uses a metal jacket outersheath from 30 gauge to 16 gauge depending on the severity of the application. For supply temperatures from 95°C to 175°C, (high temperature water and steam) isocyanurate foam or calcium silicate insulation is recommended.

The foam insulation systems are normally applied to the pipe at the factory so that only field connections require insulation and moisture protection during installation. Figure (11A) demonstrates the method.

In the case of utilidor application, the utilidor itself is usually insulated and may also act as the chase for the municipal services.

Pipe joining methods include mechanical grooved pipe with special gaskets and couplers, welded, and threaded. Underground piping is usually welded while above ground pipe may be mechanically grooved, threaded or welded. Threaded pipe is usually limited to 50 mm Ø and smaller. Branch tees may be flanged, threaded, grooved or welded.

Allowance must be made throughout the system for expansion, venting and draining. In the case of steam piping, the pipe must be sloped towards low point traps throughout. For each branch take-off, isolation valves are provided.

Mechanically grooved piping does not normally require expansion loops as the joint is free to move within specified limits. Care must be taken during installation to compensate for the initial "slack" in the system and the temperature extremes to which the system will be subjected. When glycol is used with water, special gaskets are required.

The advantage of the grooved pipe system is that installation does not require skilled labour for joining, although the couplers and fittings are somewhat expensive. This system is not suitable for steam service. Welded pipe offers the most durable arrangement for distribution mains, and is the method recommended for underground application. Expansion arrangements must be designed into the system.

In order to conform to the local requirements of the generator ground grid and ground fault systems, dielectric couplings are normally installed at the utility fence, to meet the same requirements as the water, telephone and sewer services to the generator station property.

A.10

REPORT DISTRIBUTION

APPENDIX A10: REPORT DISTRIBUTION

It is suggested that the distribution of this report should include the following:

1) Power Generating Utility Companies

Alberta Power Ltd., Edmonton, Alberta

Bowaker Power Co. Ltd., Deer Lake, Newfoundland

B.C. Hydro & Power Authority, Burnaby, B.C.

Calgary Power Ltd., Calgary, Alberta

Great Lakes Power Corp. Ltd., Saulte Ste. Marie, Ont.

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ii) Other Related Associations and Groups

Alberta Chamber of Resources, Edmonton, Alberta

Alberta Forestry Association, Edmonton, Alberta

B.C. & Yukon Chamber of Mines, Vancouver, B.C.

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Council of Forest Industries, Vancouver, B.C.

Dept. of Forest Resources & Land, St. John's, Nfld.

Fisheries & Environment Canada, Downsview, Ont.

Forest Engineering Research Institute of Canada, Pointe Claire, P.Q.

Institute of Northern Studies, Saskatoon, Sask.

Manitoba Forestry Association, Winnipeg, Manitoba

Municipal & Community Affairs, Government of Yukon, Whitehorse, Yukon

N.W.T. Chamber of Mines, Yellowknife, N.W.T.

Nova Scotia Lands & Forest Association

Ontario Forest Industries Association, Toronto, Ont.

Ontario Forestry Association, Toronto, Ont.

Ontario Mining Association, Toronto, Ont.

Provincial Lands and Forests, Montreal, P.Q.

Provincial Planning Office, Dept. of Municipal Affairs and Housing, St. John's, Newfoundland

Quebec Asbestos Mining Association, Montreal, P.Q.

Quebec Metal Mining Association, Montreal, P.Q.

Saskatchewan Forestry Branch, Prince Albert, Sask.

Statistics Canada, Ottawa, Ontario

Town Planning & Lands, Dept. of Local Government, Government of the N.W.T., Yellowknife, N.W.T.